1319 Issued June 13, 1911.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 239.

A. C. TRUE, Director.

IRRIGATION IN THE SAN JOAQUIN VALLEY, CALIFORNIA.

BY

VICTOR M. CONE,

Irrigation Engineer.

UNDER THE DIRECTION OF

SAMUEL FORTIER,

Chief of Irrigation Investigations.

[Based on work done in cooperation between the Office of Experiment Stations and the State of California.]

WASHINGTON:

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OFFICE OF EXPERIMENT STATIONS.

A. C. True, Director.
E. W. Allen, Assistant Director.

IRRIGATION INVESTIGATIONS.

Samuel Fortier, Chief.
R. P. Teele, Assistant Chief.

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C. E. Tait, Irrigation Engineer, in charge of work in southern California.
S. O. Jayne, Irrigation Manager, in charge of work in Washington.
Frank Adams, Irrigation Manager, in charge of work in California.
W. W. McLaughlin, Irrigation Engineer, in charge of work in Utah.
P. E. Fuller, Irrigation Engineer, in charge of work in Arizona and of power investigations.
W. L. Rockwell, Irrigation Manager, in charge of work in Texas.
D. H. Bark, Irrigation Engineer, in charge of work in Idaho.
Milo B. Williams, Irrigation Engineer, in charge of work in humid sections.
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Gordon H. True, University of Nevada, in charge of work in Nevada.
W. B. Gregory, Tulane University of Louisiana, in charge of rice irrigation in Louisiana and Texas.
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IRRIGATION FARMERS.

John H. Gordon, R. G. Hemphill, W. H. Lauck, R. E. Mahoney, and John Krall, Jr.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., February 24, 1911.

Sir: I have the honor to transmit herewith a report on irrigation in the San Joaquin Valley, Cal., prepared by Victor M. Cone, irrigation engineer, under the direction of Samuel Fortier, chief of irrigation investigations of this office. The work on which this report is based was done in cooperation between this office and the State of California, each paying one-half the expense.

The San Joaquin Valley includes nearly half the valley lands of California, and is noted for its productivity and adaptability to a wide range of crops. Irrigation, however, is necessary throughout the greater part of the valley to bring about the highest development. This report shows the possibilities and advantages of irrigation and the cost of water.

Mr. Cone desires to thank R. C. Benson, Paul Bailey, W. E. Packard, J. G. Newman, and E. A. Brown for their assistance in collecting field data. It is recommended that this report be published as a bulletin of this office.

Respectfully, A. C. True, *Director.*

Hon. James Wilson,
Secretary of Agriculture.

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GENERAL DESCRIPTION.

Approximately 15,000,000 acres of the 100,000,000 acres of land in California are fertile valley lands, and 7,368,000 acres, or about one-half of the entire area, are in the San Joaquin Valley. The valley occupies a central position in the State, and has a length of 250 miles, from the Tehachapi Mountains on the south to Suisun Bay and Cosumnes River on the north, and an average width of about 40 miles, from the Sierras on the east to the Coast Range on the west. The drainage waters of this level-floored depression, thus hedged in on three sides by mountain ranges, join those of the Sacramento Valley at Suisun Bay and pass through Golden Gate into the Pacific Ocean. (Pl. I.)

The mission fathers cultivated the soil and practiced some crude irrigation along the coast as early as the latter part of the eighteenth century, but they did not enter the interior valleys, and the history of actual development of this area did not commence until about the middle of the nineteenth century. Probably the first party of white men to traverse the San Joaquin Valley was a band of 40 trappers under the leadership of Jerediah Smith, who crossed the Sierras in 1825. They reported the arid plains of the valley as scantily provided with vegetation and roamed by herds of elk, wild horses, and cattle. No part of the United States at that time was so densely populated with Indians as was this great central valley, but a violent epidemic in 1833 almost annihilated these tribes. They were of a very low type of civilization, living off nuts, fish, and game, and providing only partial shelter for themselves. They did not even attempt to cultivate the soil, and it was a truly virgin soil, therefore, when the first white men came.

Little advancement was made under Spanish and Mexican rule, and in 1841 there was only one house in the San Joaquin Valley. Agriculture with its attendant labors did not appeal to the Spanish and Mexicans so long as the hides and tallow from the wild herds

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returned an easy living. The Mexicans, realizing that such conditions could not prevail long if the number of Americans increased in California, passed a law against the intrusion of the Americans, but this did not deter large companies of settlers from crossing the plains in 1841–42. Frémont's expedition and the Mexican War followed and resulted in the annexation of California to the United States.

The great migration caused by the discovery of gold in 1848 was largely responsible for the early development of all parts of the State. Towns sprang up, merchandising commenced, and agriculture gradually followed the coming of these adventurous prospectors and miners, who settled throughout the mountains and along the streams.

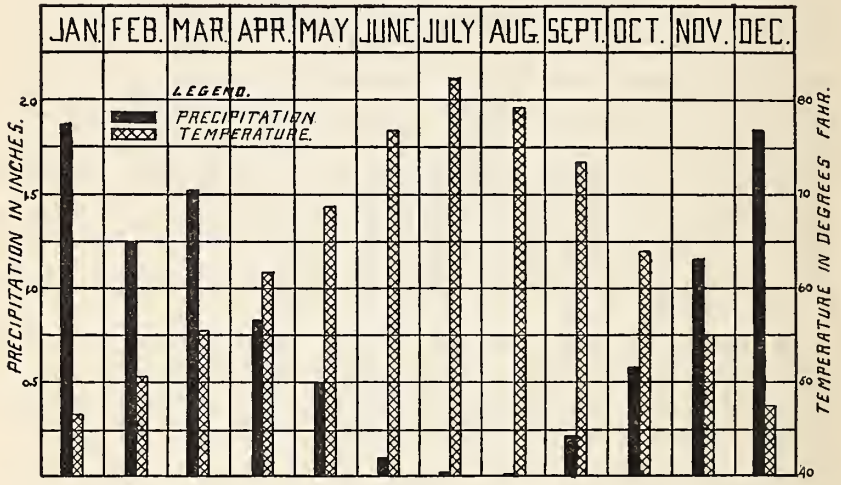

FIG. 1.—Average mean monthly precipitation and temperature of ten stations.

CLIMATE.

The main characteristics of the climate of San Joaquin Valley are warm, dry summers and moderate winters, during which the greater part of the rainfall occurs. The temperature increases and rainfall decreases from north to south.

The mean monthly temperature and the normal monthly rainfall, as given by the United States Weather Bureau,[1] have been averaged for 10 stations in the San Joaquin Valley and are shown graphically in figure 1. The records of the several stations cover periods of 21 to 39 years, and 60 years in the case of Stockton. The average annual rainfall at the 10 stations is 9.92 inches, but this does not give a fair

[1] U. S. Dept. Agr., Weather Bur. Ann. Summary, Cal. Sec., 1909.


KERN COUNTY
KINGS COUNTY
TULARE LAKE
TULARE COUNTY
FRESNO COUNTY
MADERA COUNTY
MERCED COUNTY
STANISLAUS COUNTY
SAN JOAQUIN COUNTY
SACRAMENTO COUNTY
SAN JOAQUIN VALLEY MAP

idea of the actual conditions, for the precipitation, as a general thing, diminishes from the north to the south through the valley, being as follows at the different points: Antioch, 12.58; Stockton, 15.41; Modesto, 11.75;[1] Newman, 11.22; Merced, 10.31; Les Banos, 7.62; Fresno, 9; Visalia, 9.94; Portersville, 8.43; and Bakersfield, 4.81 inches. The average precipitation is approximately doubled in the unusually wet years, and about cut in half in years of drought. The total average rainfall for the three summer months of June, July, and August is only 0.14 inch, and it is not uncommon to have a period of 100 days or more during the summer without any rain. The summer rains, being so very light when they do occur and being followed by hot sunshine, do but little good and often do much damage to the crops. About 65 per cent of the rain falls during the four months from December to March, inclusive; 76 per cent in the five months from November to March, and 85 per cent in the six months from November to April. The normal temperature does not give a fair idea of heat conditions, as an average of 90° F. for 24 hours might result from a maximum of 110° during the day and a minimum of 70° during the night. Unlike the rainfall, the temperature increases as you go south through the valley, the average annual temperature being 59.3° at Stockton, 63.2° at Fresno, and 66.4° at Bakersfield. Day temperatures of 100° to 110° are common throughout the valley, and occasionally 116° is experienced, but the nights throughout the summer, with very few exceptions, are cool enough to demand covers for comfortable sleeping. The winters are very moderate, ice and snow being practically unknown, as is evidenced by orange trees being grown in the dooryards on the floor of the valley. The oranges, however, thrive best in the thermal belt along the foothills.

The dryness of the atmosphere is an important factor in rendering the summer climate tolerable. Men work in the fields throughout the hottest days with comparative comfort, and cases of sunstroke are unknown. The following table of Weather Bureau records gives the average percentage of mean relative humidity at 8 p. m. for points in different sections of the United States for a period covering 14 to 25 years. Fresno is fairly typical of the San Joaquin Valley; Sacramento, of the lower portion of Sacramento Valley; and San Francisco, of coast conditions, while Oklahoma City, Okla., and Nashville, Tenn., have about the same latitude as Fresno and represent conditions in the humid part of the United States.

[1] Average 1889 to 1909, 11.75 inches; for 1871 to 1909, 9.94 inches.

Mean relative humidity at 8 p. m. for different points in the United States.

Month.	Fresno.	Sacramento.	San Francisco.	Oklahoma City.	Nashville.
December	70	76	75	70	69
January	71	76	75	67	64
February	57	67	70	64	68
Average (90 days)	66	73	73	67	67
March	49	62	71	58	62
April	34	57	71	53	56
May	27	54	72	64	57
Average (92 days)	37	58	71	58	58
June	19	47	72	60	61
July	14	42	77	57	61
August	16	44	79	52	63
Average (92 days)	16	44	76	56	62
September	22	44	73	56	60
October	37	52	72	55	57
November	47	62	71	62	74
Average (91 days)	35	53	72	58	64
Annual average	39	57	73	60	63

The sun in the summer shines about 95 per cent of the possible time in the San Joaquin Valley.

SOILS.

The soil of the San Joaquin Valley in general may be described as sandy, but as might be supposed in an area of so much magnitude there are various grades of sands and sandy loams. Streaks and patches of heavier soils occasionally are found along the foothill slopes and especially in the overflow lands along the rivers. The character and distribution of the different grades and types of soils depend upon the streams that have carried the materials from the mountains and have deposited them on the floor of the valley. The granitic rocks of the Sierras have produced the sandy loams of the east side of the valley, while the softer, more rapidly disintegrated rocks, such as serpentines, sandstones, shales, and clays of the Coast Range, have given to the west side its deep, mellow, loamy soil. In addition to these soils there are the peats of the islands, the tule lands in the extreme northern portion of the valley, and the adobes of the surrounding lands. The tule lands are affected by the tidewaters but are very fertile when reclaimed.

Arid lands in general are to a greater or less extent underlain with hardpan, and the San Joaquin Valley is no exception, as both red and white hardpan occur in isolated bodies throughout its area. The red hardpan is a cemented sandy material, which neither roots nor water can penetrate. The occurrence of white hardpan is more

general, but is confined principally to the east side of the valley. It consists of clay, silt, and sand, with carbonates of lime and magnesia as cementing materials, and contains varying amounts of soluble salts. This hardpan is not continuous, varies from 1 to 5 feet in thickness, and is covered with from 1 foot to many feet of soil. It is underlain usually with quicksands or water-bearing sands, but is practically impervious to water and roots, except at occasional thin, broken, or cracked places. Proper moisture conditions can not be maintained, and the development of plant roots will be restricted unless there be 3 feet or more of soil above the hardpan. Fortunately a considerable portion of the valley has a surface soil of sufficient depth for plant growth.

Arid lands generally contain more or less alkali. The San Joaquin Valley, in its virgin state, was quite free from surface alkali in injurious quantities, but much of the soil was impregnated with soluble salts to a considerable depth. A part, though not all, of the alkali was carried by the white hardpan. The ground-water level, with the advent of irrigation, crept nearer the surface as the soil became saturated, and the soluble salts were thus brought to the surface and were deposited when the water evaporated. Through this process much land has been rendered unproductive by the wasteful methods of applying water and the lack of proper drainage in the early years of irrigation. The presence of hardpan near the surface renders the alkali problem more serious, because it retards the downward percolation of water that would tend to wash the alkali from the surface soils. Both white and black alkali occur in the valley, but with improved methods of cultivation and irrigation and general adoption of drainage practice not only could the spread of the damage be checked but lands that have been rendered unproductive could be reclaimed.

PHYSICAL FEATURES.

Practically the only break in the physical appearance of the San Joaquin Valley is where the alluvial fans thrown out by Kings River and Los Gatos Creek have joined in a low ridge across the trough of the valley, forming Tulare Basin. The south one-third of the valley, from Kings River delta to the Tehachapi Mountains, is therefore, under normal conditions, without a surface drainage outlet. Kern Lake has been drained and provided with levees to prevent the Kern River waters from entering it, and the dry bed is now cultivated. Buena Vista Lake has been improved with embankments and converted into a storage reservoir for the irrigation of lands southwest of it, the water supply being obtained from Kern River and other waters formerly entering Kern Lake.

The waters from streams south of the Kings River delta, with the exception of the quantity stored in Buena Vista Reservoir and that diverted by canals directly for irrigation, are discharged into Tulare Lake. Kings River when at normal stage flows through Fresno Slough, which in turn flows into the San Joaquin River, but a large part of the flood water of Kings River goes south into Tulare Lake, unless the surface of the lake is higher than Kings River delta, in which case the overflow from Tulare Lake goes north through Fresno Slough. Several years with no unusual floods allowed the waters to evaporate, until in 1905 a great part of the lake bed was dry and under cultivation, and a network of irrigation canals covered the east and north sides. The high waters of the following years refilled the lake to a maximum depth of 13 feet and a total surface area of about 355 square miles in 1909. It has been many years, however, since there has been any overflow from Tulare Lake into the San Joaquin River.

Practically all of the water reaching the central trough of the valley comes from the streams draining the Sierras. These streams are more important in every way than those from the Coast Range on the west. The fact that the Sierra streams have their origin in the high snow-clad peaks, that their drainage basins are far larger and have better brush and forest protection, and that the rainfall is heavier, tend to give a much greater and less intermittent flow than that of the streams on the west side. This unequal distribution of drainage ways of any consequence has resulted in the axial line of lowest depression of the valley being much nearer the western than the eastern foothills. It also has caused the east side, which is the bulk of the valley, to have a grade of about 5 feet to the mile in the floor of the valley, increasing gradually to 20 or 30 feet near the foothills, while the west side has a minimum grade of about 8 feet per mile, and 20 to 40 feet per mile is not unusual.

WATER RESOURCES.

SURFACE SUPPLY.

Kings River delta divides the valley into two distinct parts, in so far as the water supply for irrigation is concerned.

The accompanying table has been prepared from records of stream measurements for 5 to 19 years, taken by the United States Geological Survey and State engineering department. The figures represent the average flow of the 14 principal streams from the Sierras, namely, Kings, Kaweah, Tule, and Kern Rivers in the southern section of the valley with an aggregate drainage area of 5,044 square miles; and the San Joaquin, Fresno, Merced, Tuolumne, Stanislaus, Calaveras,

Mokelumne, and Cosumnes Rivers, and Chowchilla and Mariposa Creeks in the northern section, with an aggregate drainage area of 7,497 square miles. There are, in addition to the above streams, several minor torrential creeks, such as White, Deer, Bear, and Poso, for which there are no records, although they are used some for irrigation.

Mean and monthly flow of the streams of the San Joaquin Valley.

Month.	Kings River, south.		North of Kings River.		Entire valley.	
	Mean flow.	Total monthly flow.	Mean flow.	Total monthly flow.	Mean flow.	Total monthly flow.
	Cu. ft. per sec.	*Acre-feet.*	*Cu. ft. per sec.*	*Acre-feet.*	*Cu. ft. per sec.*	*Acre-feet.*
January	2,148	132,091	7,158	440,138	9,306	572,229
February	2,421	134,456	11,186	621,264	13,607	755,720
March	4,633	284,890	19,851	1,220,625	24,484	1,505,515
April	7,208	428,880	24,112	1,434,900	31,320	1,863,780
May	12,425	763,995	32,516	1,999,190	44,941	2,763,185
June	12,724	757,200	28,741	1,710,600	41,465	2,467,800
July	6,139	377,487	11,344	697,593	17,483	1,075,080
August	1,989	122,295	2,936	180,389	4,925	302,684
September	921	54,810	1,204	71,640	2,125	126,450
October	998	61,380	1,936	119,040	2,934	180,420
November	976	58,080	2,639	157,050	3,615	215,130
December	1,138	69,967	3,652	224,440	4,790	294,407
Total	53,720	3,245,531	147,275	8,876,869	200,995	12,122,400

Four million one hundred and sixty thousand of the 7,360,000 acres in the floor of the valley lie south and 3,200,000 acres north of the upper portion of the San Joaquin River. About 4,800,000 acres, or two-thirds of the total, are irrigable, of which 2,350,000 lie south and 2,450,000 acres north of the San Joaquin River. The southern portion has, therefore, a drainage area two-thirds as large, a valley one and one-third as large, an irrigable area of about equal size, but only one-third as much water as the northern part. Tulare Lake was not included in considering the irrigable area, because of the present uncertainty of farming conditions over the 500,000 acres in its bed. The waters recede after successive years of light rainfall, until practically all of the dry lake bed has been cultivated at times; but during the wet years the farmers have been driven back, irrigation canals completely inundated, and the greater part of the area has been covered again by the accumulation of drainage water. Several plans have been proposed for draining Tulare Lake and utilizing its waters on the west side of the valley, but it is hardly probable that agricultural development will be sufficiently rapid to make such an undertaking feasible for several years at least. The lowlands along the river that are subject to overflow have been included in the irrigable acreage, because a part of such lands has been protected by levees and is irrigated, and similar treatment will doubtless be given

the rest. This applies also to the tule islands near Stockton, for of the 325,000 acres in the tidewaters about 250,000 have been reclaimed and are under irrigation. The irrigable lands on the west side of the San Joaquin aggregate about 540,000 acres. The area considered to be nonirrigable is that portion of the valley basin that can not be reached by gravity canals, in addition to the lake and river areas that are impracticable to reclaim at present.

GROUND WATERS.

The supply of surface waters of the valley is not sufficient to irrigate all of the lands classed as irrigable, and it is therefore very fortunate that the ground waters are abundant. Artesian wells are scattered throughout the valley and discharge their waters on the surface, but the fact that wells bored almost indiscriminately will furnish a large pump supply with a small lift is of far greater importance. The development of the ground waters is becoming very rapid, and it is practically proven that a large area is underlain with an immense volume of readily accessible water of high quality. Many of the flowing wells were drilled to obtain water for stock and have been valued so lightly generally that they have been allowed to waste water for years without attempting to control their flow or to utilize the surplus for irrigation. It is interesting in this connection to note that on the Merryman ranch near Exeter it is considered profitable to pump water to a height of 460 feet for irrigation purposes. The average lift, however, for citrus fruits in this region is about 200 feet. Probably the highest lift for irrigation in the world—586 feet—was formerly used on this ranch, and was abandoned, not because pumping to such heights was considered unprofitable, but because the soil on the top of the hill was found to be poorly adapted to citrus trees. The cost of pumping that will permit a profit depends upon the value of the products irrigated, and practically all of the pumping failures throughout the valley may be attributed to a lack of such consideration. The high cost of pumping water in the citrus belt of the Sierra foothills around Exeter, Lindsay, and Portersville is justified; but, on the other hand, although the greatest economic lift has not been established, the irrigation of most deciduous fruits, cereals, or alfalfa at such a cost would mean financial ruin.

The west slope of the valley, being largely without surface waters, would be enormously benefited if ground water were accessible. The supply, however, is quite limited, lies at a considerable depth below the surface, and in a great measure is so strongly impregnated with salts as to render it undesirable for irrigation.

AGRICULTURAL AND HORTICULTURAL DEVELOPMENT.

The early settlers on the arid plains of the valley were stock raisers, who valued the land for grazing purposes only. They enjoyed free use of unlimited range for their cattle until the business attained such prominence that many obstacles were encountered by the first people who tried to engage in agriculture. The opposition to a fence law and personal conflicts between the cattlemen and farmers were similar to those that have been experienced in many sections of the West.

Probably the first attempt at forming an agricultural settlement in the San Joaquin Valley was in 1850, when a party of 15 men settled on the Kaweah River. They, however, disobeyed the order of the hostile Indians, who gave them 10 days in which to move on, and all but two were massacred. Later the Indians were driven into the hills and a successful settlement was made near the present town of Visalia. The success which rewarded their early efforts at irrigation caused a spread of the practice to other sections of the State and encouraged farming.

Grain raising throughout the valley returned large profits at first, due to great fertility of the soil, but after several years of continuous planting to one crop it became necessary to rest the land alternate years by summer fallowing. Profits dwindled through decreased yield until it was only by farming large acreages that grain raising paid. Dry farming paid well during years of unusual rainfall, but left many years of light crops or total failure. This element of uncertainty induced the farmers to irrigate their grain, and the evolution from grain to alfalfa, trees, and vines was a natural result of greater profits. To-day the form of farming that depends upon rainfall alone is passing rapidly from the San Joaquin Valley. The development of agriculture, horticulture, and irrigation has come hand in hand. Before the first irrigation of grain was attempted near Fresno the land could scarcely be sold for $2.50 per acre, but as soon as the results of irrigation became known land sales increased and $25 to $30 per acre was given freely for the raw land, which now, when in deciduous trees or vines, is worth $250 to $500 per acre. The citrus lands of the foothills, that now sell for $1,500 to $2,000 per acre when in full bearing groves, would be valueless without irrigation. The unirrigated $15 wheat land of to-day is the $100 alfalfa land of to-morrow.

Certain localities have wide reputations for producing special crops, just as Fresno is known as the "home of the raisin," but the greatest asset of the San Joaquin Valley lies in the great variety of crops that will thrive there. Within one colony, and possibly on a

single acre, may be seen alfalfa and corn, peaches and oranges, melons and sugar beets, all well suited to the soil and climate. Such a condition permits of diversified farming in the broadest sense of the term, or the production on an area of a single crop, as may be desired. About 200,000 acres are planted in grapes for raisins, wine, and table uses. There is also a large acreage of deciduous fruits for drying and canning purposes. The growing of alfalfa under irrigation meets with great favor, especially in the newly settled districts where quick returns are necessary, and the effect of irrigation on the building up of the dairy business of the State is very noticeable. The butter output of those counties in which there has been little development in irrigation has actually decreased in the past few years, while the counties in which irrigation has been extended have increased their output. Green forage crops, such as alfalfa grown by irrigation, have advanced in the San Joaquin Valley counties until these counties now produce more than one-third of the total output of butter of the State.

POPULATION.

The following table has been prepared from the reports of the State board of equalization and State board of trade for 1908. Although these figures are doubtless not correct for the present time, still the comparisons will be quite fair to all parts of the valley:

Valuation and population of the San Joaquin Valley.

	Kings River, south.	North of San Joaquin River.	Total in valley.
Valuation of agricultural lands	$50,000,000	$55,000,000	$105,000,000
Valuation of improvements on agricultural lands	$11,000,000	$10,000,000	$21,000,000
Population, including towns and cities	142,000	151,000	293,000

It is seen from the above that 7,368,000 acres in the floor of the valley support 293,000 people, or a trifle over 25 to the square mile, but approximately 100,000, or one-third of the population, live in the towns and cities. Considering an average-sized family to be five, the present population would give 125 acres to each family in the valley, while if only two-thirds of the people are considered as interested in agriculture, the average-sized farm is 190 acres per family. If the entire valley should be placed under irrigation and devoted to intensive cultivation, it should support, conservatively, 100 people per square mile, or about 1,200,000 people. The entire floor of the valley, however, can not be irrigated, principally owing to the insufficient water supply, and though the above theoretical figures are probably too large, they show the possibilities of future development.

TRANSPORTATION FACILITIES.

Transportation facilities generally are good throughout the valley. There are over 1,400 miles of railroad tracks, not including sidings and spurs, principally under the control of two transcontinental companies—the Southern Pacific and the Santa Fe—whose lines traverse the entire length of the valley and whose branches serve a large part of the territory. The San Joaquin River is navigable at all times of the year as far up as Stockton, and gives the lower portion of the valley the double advantage of railroad and steamer communications with San Francisco. There are also nearly 100 miles of interurban electric lines in operation, and there doubtless will be a great increase in the near future. Little attention has been paid to the betterment of highways, but good-road movements are being considered in several localities. In contrast with conditions in the humid States the roads of the San Joaquin Valley, being sandy, are best during the winter months. The use of heavy crude oil is becoming general on very sandy roads, but there is still much room for their improvement.

THE COLONY SYSTEM.

One of the most prominent features in the development of the San Joaquin Valley has been the colony system of settlement, and it seems probable that much of the future growth will be accomplished in a like manner. The original colonies, covering 1,000 to 5,000 acres each, with wide stretches of arid land between them, were scattered around a few towns, but further settlement has closed the gaps and welded the community around each town into one solid mass and rendered the colony boundaries imaginary. The customary method has been for the promoter to secure from 1 to 10 sections of land, subdivide them into 10 and 20 acre lots, construct irrigation ditches on the highest land so as to make them easily accessible to each lot, checkerboard the tract with roads each half mile, and sell the lots with perpetual water rights to homeseekers.

There are many advantages in this colony system. The purchasers are given a long time in which to pay for the land, a uniform system of ditches is provided, and that great bugbear of the pioneer—lack of neighbors—is overcome. It also is the means of breaking up the large landholdings, and therefore tends toward a more intensive cultivation. Local markets also spring up more rapidly than is the case where farms are scattered.

That all the colonies have not been successful is due to the abuse rather than to any fault of the method. There have been very few cases of failure, and all of those were due to poor land and unscrupulous promoters. It has been the height of folly to induce settlers

from humid States and foreign countries, wholly unfamiliar with local conditions or with the form of agriculture necessary with irrigation, to buy poor lands, especially when there is an abundance of good land. Farmers well versed in irrigation practice and cropping and cultivating soils in the arid region might have succeeded where newcomers failed, but more fertile soil would have compensated for the lack of experience. Such failures have reflected on the surrounding country and retarded the development of the good land. Recent attempts at such fraudulent practice have been exposed by the honest promoters, and much good will result from honest colonization practice.

OIL.

Although oil has been produced in Kern County for over 20 years, it was not until after the discoveries in 1899 that extensive development began. Kern and Fresno Counties, in the southern portion of the San Joaquin Valley, are the chief producers. They are largely responsible for making oil the leading mineral industry of the State and have added thereby greatly to its wealth. It has partially solved the fuel question for the railroads and power plants on the coast, and is the source of asphalt and road oils in addition to the lighter oils which are derived by distilling the crude product. Pipe lines have been extended from the oil fields through the valley to San Francisco Bay and across the mountains to the coast at Monterey. Tank cars, often in full trains, pass back and forth constantly, and there are many other evidences to remind one of the importance of the industry.

STREAMS AND LANDS IRRIGATED.

KERN RIVER.

Kern River, which is in the extreme southern portion of the San Joaquin Valley, receives the run-off from an area of 2,345 square miles of the Sierras. The stream bed is only 3 to 5 feet below the land level and the materials eroded from the watershed have formed a delta where the river channel has been changing constantly. The waters formerly found their way into Kern and Buena Vista Lakes, and from there the overflow went through numerous shifting sloughs to Tulare Lake, but since irrigation systems have been perfected the water has been confined to permanent channels. Overflowing of the delta lands has been largely prevented by diverting a considerable portion of the flow of the river for irrigation purposes and by levee systems, but unusually large freshets, caused by heavy rains falling on the large snow deposits in the mountains, do great damage, because

many sloughs and channels have been obstructed to reclaim the land for irrigation and the restricted main channel of the river will not carry the excess of water.

The average monthly flow of the Kern River, as computed from measurements taken at Rio Bravo for the years 1879–1883, inclusive, and at Bakersfield for the three years 1894–1906, inclusive, and 1909, making a total of 19 years, is shown in figure 2.[1] The average annual flow is 902 cubic feet per second, which makes the Kern River the eighth in size of the San Joaquin Valley rivers, but the acreage irrigated from it is third largest. The river reaches its highest stage in May and June, and there is little irrigating done after July. The flow is greatly decreased from September to February or March.

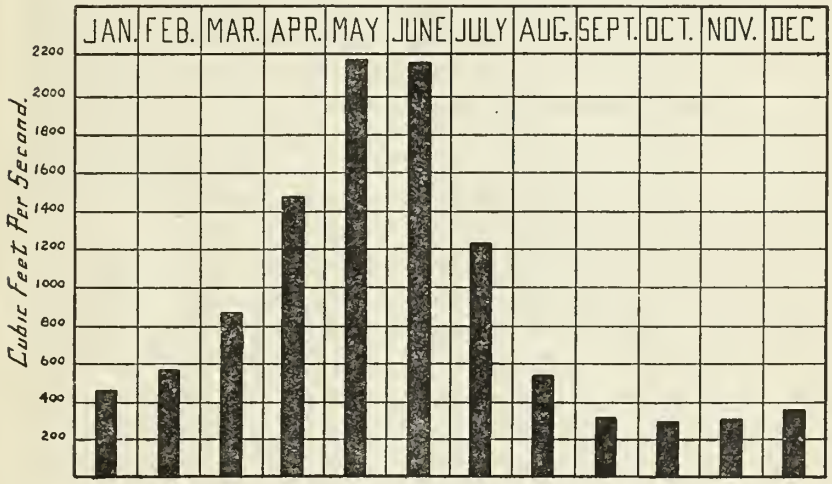

FIG. 2.—Average monthly discharge of Kern River.

Practically the entire flow of Kern River is controlled by two companies, the Kern County Land Co. and the Kern Valley Water Co., the latter being a Miller & Lux organization, and the former having succeeded to the rights of J. B. Haggin et als. All the other companies except two cooperative associations, the McCaffrey Ditch Co. and the Castro Ditch Co., operating 1.75 and 3.75 miles of main canal, respectively, have become defunct, and the canals when used are handled as private ditches without the control of any organization except the Kern County Land Co., which uses most of the water delivered to the ditches. Irrigation from the Kern River began in 1858–1860, when small canals were built for the irrigation of grain.

[1] Figures 2 to 13, inclusive, are based on stream measurements made by the California State engineering department for the years 1879–1883, inclusive, and by the U. S. Geological Survey for years since 1883. The records of these measurements have been published in U. S. Geol. Survey Water-Supply and Irrig. Papers 81, 85, 100, 134, 177, 213, and 251, and Bul. 140.

Development was not rapid, however, and in 1873 there were only six canals, watering an aggregate of 5,000 acres, and only one dam, a brush and gravel structure, which was subsequently abandoned.

A legal war was started in 1875, which resulted in the Miller-Haggin agreement of July 28, 1888, which is the basis of the present division of the waters of the river. This agreement provides that the water of Kern River is to be measured at two points, the first one about 5 miles above Bakersfield (sec. 2, T. 29 S., R. 28 E.) and the other about 23 miles farther down the river (sec. 23, T. 30 S., R. 25 E.). From March to August, inclusive, if the water at the first point exceeded 300 cubic feet per second, Henry Miller et al. (now Kern Valley Water Co.) were to receive one-third of the excess, measured at the first point, delivered undiminished at the second point. During the remaining six months of the year J. B. Haggin et als. (now Kern County Land Co.) were entitled to all the water above the second point except 300 cubic feet per second, which belongs to Kern Island. Any water passing the second point from September to April belonged to Miller et al. The agreement also permitted the use of Buena Vista Lake as a reservoir, defined its boundaries, and prohibited storage in Kern Lake. The reclaimed dry bed of the latter lake is now cultivated.

The Kern County Land Co. is the parent or controlling company of the Kern County Canal & Water Co., which itself is a holding company for 16 subsidiary canal companies which divert water from the river between the foothills and Buena Vista Lake Reservoir. The main canals operated by these canal companies vary in length from 1 to 33 miles, there being 9 companies operating an aggregate of 100 miles of canals on the south side of the river and 7 operating 82.5 miles of canals on the north side. The Kern County Canal & Water Co. takes no active part in the management of the various canal companies other than acting as treasurer for each company. There are sundry low diversion weirs in the river, but several of the canals are merely extensions of other canals and do not take their supply directly from the river.

The canals which divert water directly from the river fill with sand during the irrigating season and have to be cleaned during the winter at considerable expense. The sand is removed by the scrapers, dredges, and sluicing weirs that have been installed recently. Part of the sand and silt is returned to the river, while some is washed through cuts in the levees.

The Kern County Land & Canal Co. charged 75 cents per cubic foot per second for 24-hour periods, or an equivalent of 37.5 cents per acre-foot. The water is measured where it leaves the main canal through overpour or undershot weirs, fairly accurate records of the

amount delivered to the irrigator being obtained by the zanjero, or ditch tender. The Kern Valley Water Co. uses the entire flow of its canals on its land and sells no water. This company's system consists of two main canals about 35 miles long and numerous distributary laterals. These canals may receive water either from the Buena Vista Lake Reservoir or from the river before it empties into the reservoir. The Button Willow district, northwest from the reservoir toward Tulare Lake, is served by these canals, about 40,000 acres, owned and farmed by Miller & Lux, being under irrigation. The greater part of this land was originally a swamp, but it has been reclaimed and is provided with water for irrigation from Buena Vista Lake Reservoir. The heavy soil requires drainage after flooding, and in many places the natural slough channels have been enlarged and cleaned to make drainage canals. The excess of water applied when flooding, is drained off and used again for irrigation several miles below the drained area.

Throughout the entire section pumping plants are used to supplement the supply of irrigation water from the gravity canals. In some instances sufficient water for flooding is obtained by pumping into small reservoirs lined with oil or sumphole sand to prevent seepage. The Kern County Land & Canal Co. has several electrically driven plants, which are operated during a season when there is a shortage of water from canals. Besides the large undivided holdings of the two companies previously mentioned, several colonies have been started on lands with limited water rights or none at all. Such settlements have not been very prosperous, but pumping is being resorted to on a large scale in some of the colonies and profitable results are expected. The climate of Kern County is in general the same as it is in other portions of the San Joaquin Valley, except that the mean annual temperature is the highest and the mean annual rainfall the lowest of any part of the valley. The highest mean annual temperature at Bakersfield for 20 years, including 1908, was 66.4° F. and the average annual rainfall 4.51 inches. The highest temperature recorded during this period was 119° F. and the lowest 19° F.[1] This light rainfall, very little of which falls between April and November, and the hot weather of summer necessitate the artificial application of water where crops are grown. Considering the limited flow of Kern River and the positive necessity for practicing irrigation, the charge of 37.5 cents per acre-foot for water is quite low.

The section that can be irrigated from Kern River extends south, west, and northwest from Bakersfield for about 25 miles in each direction. All of this is not irrigated at the present time, however, the water supply being limited, and a considerable portion of the

[1] U. S. Dept. Agr., Weather Bureau Ann. Summary, Cal. Sec., 1908.

land being swamp and alkali land that has not been reclaimed. The soil throughout the section is variable, and the several types often are found close together. The soil of Kern Delta proper includes both sand and peat loams, while in that of the southern and western parts there is considerable clay. The soil is heavier in the vicinity of Buena Vista Lake Reservoir and that strip of irrigated land to the northwest, while to the north of the river the soil is a sandy loam. Throughout the section more or less alkali is found, especially in a long strip to the east of the swamp area. The underlying strata of clay or sand or hardpan, which usually are found from 2 to 5 feet below the surface, vary as much as the surface soil.

In the vicinity of Bakersfield the water table is 2 to 4 feet below the surface. Throughout the remainder of the section the depth varies from 7 to 12 feet, with the exception of the northernmost lands, where the depth is 40 to 60 feet. This high water table is in a great measure responsible for the high duty of irrigation water.

The principal crop grown by irrigation is alfalfa, which is irrigated by means of contour checks. The levees are constructed on 1-foot contour lines, very little leveling is done inside the checks, and consequently an unequal distribution of the water results. The material required for the levees is taken from the high side of the adjoining lower check. The contour lines follow the general slope of the land, and small knolls and swales are not taken into consideration. The average size of checks varies from 3 to 7 acres. Three to five cuttings per year are obtained, the number depending upon the season and the amount of pasturing. The alfalfa is fed locally, and the majority of farmers cut only enough hay for use and pasture the land the remainder of the season.

Grain is also irrigated by means of contour checks. The checks for grain land are larger than those for alfalfa, the size ranging from 7 to 15 acres, and even from 75 to 100 acres in some instances. The cost of irrigating ranges from 40 to 75 cents per acre, although on some of the large ranches it is as low as 5 cents per acre. The area in orchards—principally prune and apricot—and vineyards is comparatively small, being only about 2,000 acres. This was much larger at one time, but a shortage of water and a dull market made it unprofitable to irrigate from pumping plants, and caused the failure of most of the orchards and vineyards.

Orchards generally are irrigated by means of contour checks or basins, the latter being preferred, as the water can be distributed more evenly. The average duty of water for alfalfa and grain lands is about 2.5 acre-feet per acre and that on orchards about 3 acre-feet per acre.

On the large ranches winter or early spring irrigation is practiced. This is done because the water supply is larger at this time, and if

irrigation is practiced during the hot summer there is danger of scalding unless care is taken that the water does not stand long in the low places. When the river is high there is considerable water wasted by the different canals; much water also passes from the river into old channels and sloughs and overflows the lowlands. Neither the water wasted by canals nor that going into the old sloughs returns to the river. On the south side of the river the greater part of the waste water is being used by the Kern County Land Co.

Northeast of Buena Vista Lake Reservoir there is a large area of arid land on which wild grasses grow abundantly when irrigated. These lands are being contour checked with a difference of 3 feet in elevation between the checks, into which the waste water is turned. The grass that springs up almost as soon as the water is turned on affords excellent pasturage for all kinds of stock. Instead of closing the levees, each alternate one is left open at the opposite end. The openings being located where the ground is highest, each check is filled before the water flows into the next one.

The canal systems depending upon Kern River for their supply extend over an area of about 300,000 acres. If the entire flow of the river could be utilized through storage and direct diversion, it would irrigate over 200,000 acres of the more profitable crops, using 3 acre-feet of water per acre, an amount which present practice indicates is ample for Kern River district. With more careful handling of the water and improvements in the canal systems it is probable that a still greater acreage could be irrigated. It is evident, however, that more storage must be resorted to before the greatest good is secured from the water supply. Buena Vista Lake Reservoir, which has a capacity of about 130,000 acre-feet, has made it possible to irrigate a much larger area than would have been possible from the normal stream flow, but at flood stages there is still considerable water wasting from Kern River into Tulare Lake. Another source of loss of water is in the 23 miles of river channel between the first and second points of measurement. The loss here during high-water stages runs as high as 20 per cent of the total flow of the river. The advisability of constructing cement-lined or oiled canals on either side of the river through that distance has been considered, but no action has been taken.

TULE RIVER.

Tule River, having a watershed of 437 square miles in the low Sierras, enters the valley just above Portersville, follows a general westerly course through Tulare County, and divides into three main channels, which in turn divide into others. There is a defined channel terminating in Tulare Lake, but with the exception of flood

periods in the spring, the flow is dissipated before it reaches the lake. The stream bed is very sandy, so that the lower channels are changing constantly. Prior to the flood of 1861–62 the main stream at Portersville ran 1½ miles north of its present location.

Although the flow of Tule River never ceases entirely above Portersville, after July 1 it seldom reaches far below that point until it is lost in the sands. The average monthly flow at Portersville for a period of 12 years, 1879–1883 and 1902–1908, is 246 cubic feet per second, and the greatest flow is from March to June, inclusive, as shown in figure 3. Judging by the aggregate annual flow, the Tule is the eleventh stream in importance in the San Joaquin Valley. There are 86 ditches and canals, having a combined capacity of about 1,250 cubic feet per second and a total length of 218 miles of mains

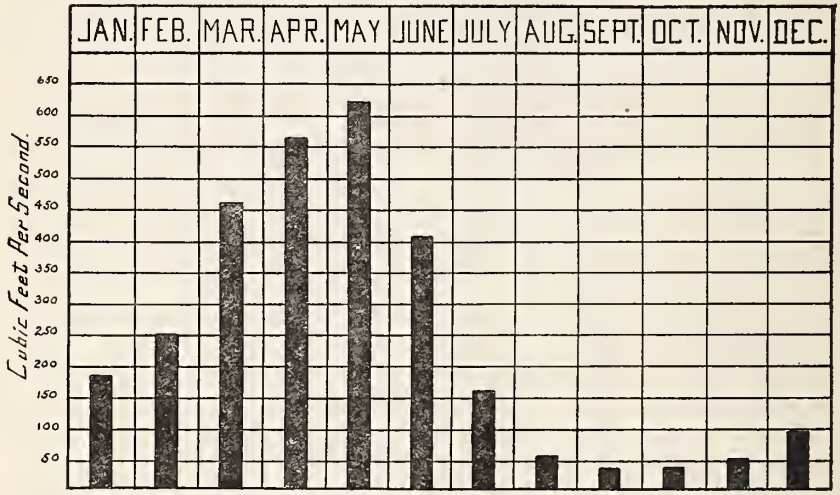

FIG. 3.—Average monthly discharge of Tule River.

that depend upon this river for their water supply. Several of these were constructed between 1859 and 1865. Part of the claims for water are based on riparian and part on appropriator's doctrine, and it is estimated that more than $200,000 has been spent in litigation concerning the water rights on this river without having made them secure. In 1909, 37 of the lower riparian owners formed an incorporated association, brought suit against all the upper ditches, and secured the right to 400 cubic feet per second during the 22 days from March 19 to April 10 of each year, the water to be measured at Aettle Bridge, below Portersville. This amount may be considered ample for all time, because the valley land along the river ordinarily is irrigated but once each season, and that during March and April.

This judgment, however, had nothing to do with the rights of the separate companies.

Nearly all of the ditches are incorporated and owned by the farmers whose land they irrigate. The water carried by each ditch is usually divided in proportion to the number of shares owned by the irrigator, and the expenses of the system are met by the assessment of stock in the company. Two companies have abandoned the above method and are now selling water at a price just sufficient to meet current expenses. Only stockholders are permitted to receive water under one ditch, but under the other ditches water is sold to non-stockholders, but at a higher rate. The price varies with the season and the scarcity of water, the average price when the river is high being 3 cents per miner's inch per 24 hours, measured under a 4-inch pressure. The rate increases through the season, until, in the fall, when pumps have to be used to supplement the supply, it reaches 25 cents per miner's inch per 24 hours. The estimated duty of water under such conditions is 1 miner's inch for 4 acres.

Most of the dams in the river are built of brush and gravel, and have to be replaced after spring freshets. There are only a few good structures in the ditches. No serious problems of construction were met in diverting water from the Tule, and in consequence there are a great number of small ditches extending only a short distance on either side of the river. The Tule River and Tipton irrigation districts, formed under the irrigation district law, constructed rather extensive systems, but these have been abandoned because of the lack of water supply and resulting litigation. A portion of the area originally included within these districts is now irrigated from some of the small canals. About 43,000 acres are irrigated from Tule River, 3,500 of which are in citrus trees, 4,000 in deciduous trees and vines, 18,000 in alfalfa and corn, the greater part of the remainder being in wild-grass pasture. The pasture land, alfalfa, and corn on the lower Tule are usually irrigated once each season, and the crops are fed to cattle and sheep. The alfalfa in the upper part of the valley receives two or three irrigations when water is available; most of the alfalfa is baled and shipped. The citrus acreage under the present ditch systems can be increased somewhat, but the greater part of the citrus trees being planted must depend solely upon pumps for irrigation. About 200,000 acres are covered by ditches and canals along the Tule River, but the natural flow will not permit of any considerable increase of the present irrigated acreage unless storage is resorted to. More profitable crops are replacing some of the alfalfa and pasture, and the irrigators are rapidly eliminating the element of chance by installing pumping plants to guarantee a water supply throughout the season.

KAWEAH RIVER.

The Kaweah River, the ninth largest stream in the San Joaquin Valley, is the principal stream in Tulare County and has a drainage area of 619 square miles in the low Sierras. It enters the valley about 15 miles east of Visalia and flows in a general westerly direction for a short distance to McKay Point, where the channel divides, part of the water continuing southwest down the Kaweah River and part going into the St. Johns River. The latter follows a winding channel in a westerly and northwesterly direction to within 4 miles of Traver, where it unites with Cottonwood Creek, forming Cross Creek, which finally joins some of the old high-water channels known as Elk Bayou, Deep, Cameron, Mill, and Packwood Creeks, which run southwesterly toward Tulare Lake. The lower parts of all these

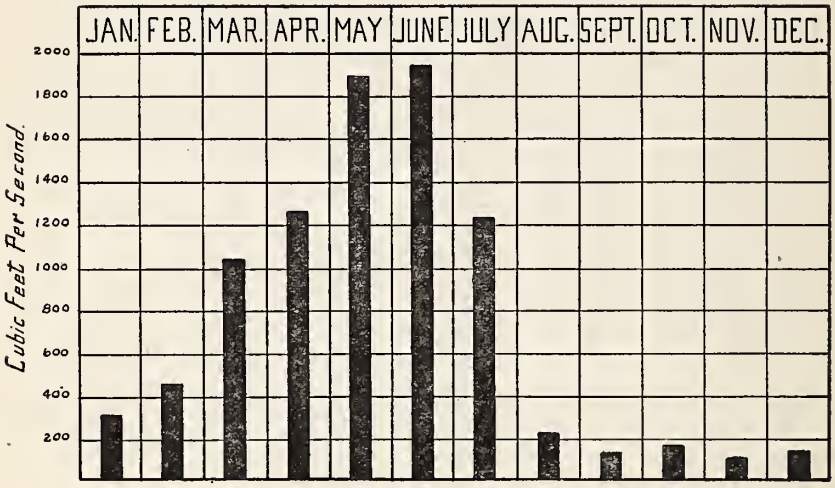

FIG. 4.—Average monthly discharge of Kaweah River.

creeks are small and often change their courses, as do the upper channels during high-water periods. The St. Johns Channel was formed during the flood of 1861–62, and has been enlarging each year, the stream bed being 8 to 10 feet lower than it was a few years ago, while portions of Deep and Mill Creeks are filling with sand so rapidly that bridges once far above the bed of the stream are now practically resting on the bottom.

The average monthly flow at Three Rivers for a period of five years—1904–1908—is shown in figure 4. The average annual flow is 731 cubic feet per second. The high-water period is during May and June, when much water goes to waste, but during the rest of the year the entire flow is diverted for irrigation. The discharge from August to February, inclusive, is often so small that no water reaches

the canal head gates below McKay Point, the water not diverted by the upper ditches being lost in the sandy bed of the river.

The first irrigation in the San Joaquin Valley was doubtless in 1853, when a ditch was built from Mill Creek, near the present town of Visalia, to furnish power for a grist mill, and water was taken from this ditch to irrigate some grain and gardens. The following year about 2 miles of ditch were built to the Watson ranch distinctly for irrigation purposes, and during the same year an acre of peach and apple trees was set out under the Matthews Ditch, which now diverts from the St. Johns River. The early history of the water rights on the Kaweah and its branches is marked by much contention and many conflicts. People were intimidated with shotguns and head gates of canals were dynamited. The companies in which stock was owned by farmers living near the river fared better than those with land far removed from the source of water supply, all of which had much bearing on the present status of adverse water rights on the Kaweah. About $400,000 was spent in litigation without satisfactorily adjusting the rights, because all of the parties interested were not in the suits, and even to-day little is known of the actual legal rights to the use of water.

Two organizations, the St. Johns River and the Kaweah River associations, were formed and agreements entered into in an effort to adjust the diversion from the river and to stop the expense of litigation. These agreements were made binding by judgments in friendly suits. Twenty-six of the 62 canals diverting water from the river are small riparian ditches in the mountains, and these, with a few of the lower canals, are not included in either of the associations. The various canal companies in each river association also have agreed among themselves as to their rights. The agreement between the two associations is essentially as follows: In the spring when more than 80 cubic feet per second is flowing at McKay Point the water is to be divided equally between the two channels, and when the flow decreases and is less than 80 cubic feet per second, the entire amount is to go down the Kaweah, and so continue until October 1 next succeeding, and if at that date there is not 80 cubic feet per second, then the entire flow shall continue down the Kaweah Channel until that amount is exceeded, when the amount again will be divided. The water is divided by the superintendents of the two associations. The above arrangement has overcome much litigation, but would be obviously more effective if all the canals and ditches on the river were parties to the agreement. It is a peculiar condition that could cause $400,000 to be spent in arriving at water rights to a fractional part of a cubic foot per second, and yet have all parties fairly well satisfied with a crude and inaccurate method of measurement, such as is used in diverting the water there at present.

The 62 canals in the agreement have an aggregate length of mains of 280 miles, 250 miles of laterals, and a capacity of 3,000 cubic feet per second. They extend over 203,000 acres, of which 105,000 are irrigated, 2,300 acres being in citrus trees, 16,000 in deciduous trees and vines, 50,000 in alfalfa and corn, and the rest in pasture and gardens. Nearly all of the ditches in this section were constructed in the early days by the settlers, several of whom would organize a company and receive stock in proportion to the work done by them in excavating the ditch. A share of stock represents a pro rata part of the flow in the canal, and the expense connected with maintaining the ditch and distributing the water is assessed against the stock. Water under the Bonnie Brae Ditch, however, is delivered by measurement to the stockholders at a sufficient charge per unit to pay operating expenses. The rock-fill dams, which were formerly used on both rivers to effect diversion during low-water stages, were cemented during the fall of 1909 to render them more permanent.

One of the largest canal systems on the Kaweah is the Tulare irrigation district, which was organized in 1889. It has head gates on the Kaweah and St. Johns Channels and 50 miles of canals, with a capacity of 450 cubic feet per second. About 37,400 acres are included in the district, but only 12,000 acres are irrigated at present.

During the period of hard times in the early nineties, when farm products were low in price and money was scarce, the farmers became discontented, refused to pay the taxes levied for the support of the district, and began litigation that lasted for eight years, during which time no interest was paid on the $500,000 of outstanding bonds. After carrying the suit to the Supreme Court of the United States the bond owners won, and in 1903 an agreement was made with them to accept $273,075 for the bonds. To raise the amount required a single tax levy of 36 per cent was made on the assessed valuation of property in the district. The cloud of depression seemed to lift when the bonds were burned, and with the return of good prices for products the district began to flourish. The operating expenses and salaries were paid during the period of litigation by toll charges instituted just before the trouble began, and this method is still in effect.

The actual irrigators, under this system of charging for water, pay the operating expenses of the district instead of assessing the cost against all in the district, regardless of whether or not they had used water. An attempt is being made at present to change back to the general taxation method, as a number of parties are being benefited by having their lands subirrigated by seepage from the canals without paying for the water. If the taxation method were employed, the area irrigated would be increased considerably and the land

would be developed more rapidly. Twelve thousand acres, or less than one-third of the total acreage in the district, were irrigated in 1909, while in 1908 there were only 1,300 acres irrigated. The amount of land served each year by the district canals varies with the available supply of water, and the charge for water is fixed by the board of directors in February so as to make the revenue meet the running expenses. A flow of about 10 cubic feet per second of water is allowed to each irrigator until his irrigation is complete, and about 30 such heads can be supplied by the canals at one time. Where water is supplied in this manner without a time limit in which to complete an irrigation, one man may use three or four times as much water as another man in irrigating equal sized tracts and yet pay no more for the water. A farmer in this district in one instance used a head of water 30 hours to irrigate 20 acres, while a neighbor used the same head 5 days to irrigate the same sized tract. The difference in the amount used is due somewhat to difference in soil and the various opinions of irrigators regarding the necessary quantity of water for correct irrigation, but generally it is true that too much water is applied when they are allowed to take all they want and pay according to the acreage irrigated. The toll charge in 1895 was 50 cents per acre per irrigation, but it has been as high as $2.50 per acre. The charge in 1908 was $1.50 per acre and only one irrigation was allowed, because of shortage of water. The charge in 1909 was $1 an acre for the first irrigation and 50 cents per acre for each succeeding irrigation, there being ample water for all who desired to use it. The charge per acre is fixed without regard to the crop to be irrigated. The irrigators must make application to the secretary, stating the number of acres he desires to irrigate and pay for the same, and the first to pay is the first to be served as the distribution is made down the canal, but the superintendent may run the water in any manner he considers best suited to the conditions. Three ditch tenders, receiving $2.50 per day each when employed, distribute all water within the district.

The improvements and structures on the canals are not kept in good repair, and near the head of the main canal drops have been allowed to wash out without being replaced until the grade of the canal is very far from uniform. No special measures are taken to clean the main canals through the irrigating season, as the current of water is sufficient to prevent much weed growth. A portion of this district is an example of the damage that results from wasteful methods of using water, from obstructing natural drainage ways to cause the water to back up and subirrigate adjoining lands, and from a general lack of drainage precautions that has caused a high water table and a surface accumulation of alkali that has interfered seriously with

plant life. The ground water in a prune orchard near Tulare has risen to within 16 inches of the surface, and the trees, which originally were in thrifty condition, have been destroyed by alkali. This condition is not confined to this one orchard, but may be seen only too frequently. Individual effort has overcome this trouble in a few cases, but there has been no concerted action on a drainage system which would be effective and moderate in cost.

Pumping plants are becoming very popular throughout the district, some being operated by gasoline engines and others by electric power, which is obtained for $25 per horsepower per six months. An abundant supply of water is obtained at shallow depths, and artesian flow often is found at a depth of 450 feet.

The principal crop in the Tulare district is alfalfa, there being about 8,000 acres, most of which is fed locally, though some is shipped. There are three creameries in Tulare that pay an aggregate of about $60,000 per month to the farmers for cream. The acreage in trees and vines is comparatively small, being only about 1,000, due to the fact that the shortage of water from the canals has made fruit growing uncertain. The installation of pumping plants, however, will insure the water supply. Corn does well with little or no irrigation where the water table is near the surface, and there are about 3,000 acres of corn in the district. There are several large sugar-beet fields in the northern part of the district that supply local factories.

The only storage reservoir being used on the Kaweah River is Bravo Lake, which lies in the valley. It has a capacity of 876 acre-feet, and is used by the Wutchumna Ditch to augment the supply during the latter part of the irrigating season. Tulare district has a storage site near the head of one main canal that is estimated to have a capacity of 13,248 acre-feet, but no use of it has been made, and there is no immediate probability of doing so. As with all the streams, especially in the southern part of the San Joaquin Valley, a reserve supply of water for the latter part of the season would be of great value to the irrigators, and on some streams many good reservoir sites are said to exist, although little advantage has been taken of them.

KINGS RIVER.

Kings River, with a drainage area of 1,742 square miles, more than one-half of which is in the high Sierras, carries the second largest volume of water of any of the San Joaquin Valley streams, and its water supply covers the largest irrigated area in the State. It enters the valley about 20 miles east of Fresno, and after flowing 9 miles through numerous coarse cobble channels scattered over a maximum width of 4 miles reunites in a single deep channel. A short distance

below Kingsburg the river takes a westerly course and has formed the delta that divides the valley into two drainage basins. The main river channels and sloughs on the south side of the delta flow into Tulare Lake, while the sloughs on the north side of the delta discharge into Fresno Slough, which in turn unites with the San Joaquin River. The river has a fall of about 9 feet per mile through the Centerville bottoms, and averages about 2 feet per mile from there to Tulare Lake. Fresno Slough has an average fall of only 6 inches per mile. The delta formed across the valley by Kings River is about 30 miles wide from north to south, and at its lowest point is 30 feet above the bed of Tulare Lake.

The average monthly flow of Kings River at Red Mountain for 13 years, 1896–1908, is given in figure 5. The average annual flow is

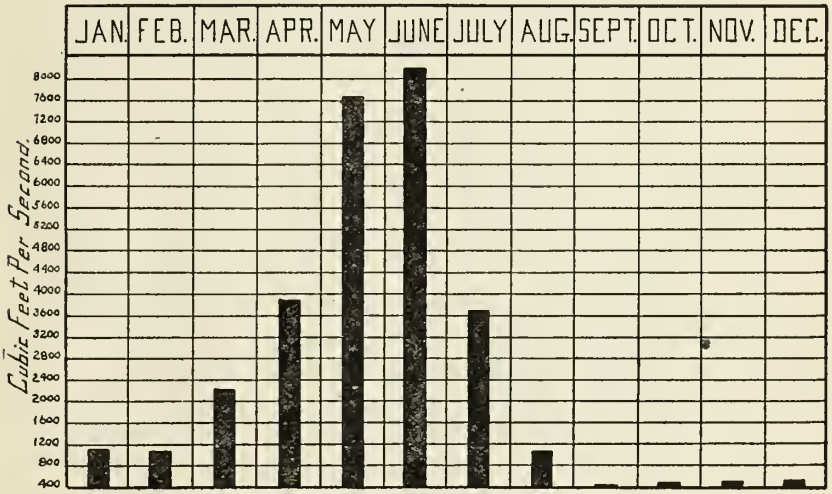

FIG. 5.—Average monthly discharge of Kings River.

2,598 cubic feet per second, but the average from September to December, inclusive, is only 400 to 500 cubic feet per second. The highest stage is reached in June, with an average of 8,207 cubic feet per second, and a comparatively large flow from March to July, inclusive, which is during the period of greatest demand for irrigation water. The large volume of water, the low banks that permit of easy and inexpensive diversion, and the large expanse of fertile valley lands that lie adjacent to it have been the important factors in making Kings River the great source of wealth that it is. It was recognized early that profitable agriculture on the sandy plains of this section depended upon the artificial application of water in addition to the average annual rainfall of 9 inches, in consequence of which development through irrigation was rapid.

Twenty-one principal canals divert water from Kings River, besides a number of small riparian ditches. The main canals have an aggregate length of 516 miles, laterals about 1,500 miles, and a maximum carrying capacity of 10,000 cubic feet per second. These systems extend over an area of 800,000 acres, of which about 650,000 acres are susceptible of irrigation and 450,000 acres are actually irrigated. Although there were several small ditches in the Centerville bottoms in the early sixties, one of the first important attempts at irrigation from Kings River was made in 1871, when a small ditch, known as the Sweem Ditch, near Centerville, was purchased and extended to near the present city of Fresno, where four sections of grain were crudely irrigated in 1872 and a fine yield secured. Other ditches on both sides of the stream were started about the same time, and their priority rights have been fairly fruitful in litigation, as is given in detail in a bulletin of this office.[1] All of the canal companies on Kings River now have entered into mutual agreements stating how the water shall be divided when there is less than enough water for all. There is still some element of discord, however, among the companies on lower Kings River regarding this means of adjudicating rights, and it is not unlikely that litigation will continue. The first few ditches have been enlarged and extended and scores of others added to keep pace with the development of the country, for improvement of agricultural and horticultural methods has compelled improvements in irrigation enterprises.

The Fresno Canal & Irrigation Co. and the Consolidated Canal Co., which practically may be considered as one system, as they are under one management and have a source of water supply in common, form one of the largest and best known irrigation systems in the State and have a network of canals covering that portion of Fresno County bounded by Kings River, Fresno Slough, San Joaquin River, and the Sierra foothills. They control practically all of the canals diverting water from upper Kings River, with the exception of the Alta irrigation district canals on the south side of the river. Litigation and poor management doubtless had much to do with the consolidation of the several canal systems in Fresno district, and it is certain that the consolidation has had a general beneficial effect. Permanent headworks have been established for diversion of water into the canals, these having been enlarged and extended so as to make it possible to turn surplus water from one into another, affording a more economical system of distribution and rendering better service to the irrigators. The old cobble dam 22 miles east of Fresno has been replaced by a reenforced concrete structure 300 feet long, 4 feet high, with a broad top and front of Ogee form, and 4 waste and

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 100.

emergency gates in the center, each 6 feet wide. The heavy reenforced concrete and timber head gates of the Fresno Canal & Irrigation Co. are located about 100 yards from the west end of the weir, while the Consolidated Canal Co. has its head gates immediately adjoining the west end of the weir, a heavy retaining wall forming a part thereof. A very novel improvement is a water wheel 9 feet 4 inches in diameter, 50 inches wide, with 2 by 4 feet paddle arms, which is set back of a center section in these head gates and by a chain-belt connection with a series of shafts and bevel gears furnishes power for raising and lowering the heavy gates. It is arranged to throw in and out of gear and has proved very efficient.

The Gould Canal, formerly known as the Kings River and Fresno Canal, is now a part of the Fresno Canal & Irrigation Co.'s system, and has a separate diversion weir on Kings River about 1½ miles above the headworks of the Fresno and Consolidated Canals. It is a low timber structure of the flashboard type, and has openings each 8 feet in the clear.

The Fresno system also has a separate diversion from Cole Slough, one of the delta channels of the Kings River, about one-half mile east of Laton, for the Grant canals which serve the greater part of the La Guna de Tache lands. Here there is a truss bridge across the slough arranged for flashboards to be inserted between the vertical posts to serve as a weir.

The combined Fresno and Consolidated systems have a total length of 466 miles of main canals and 1,200 miles of principal laterals, and divert about 2,800 cubic feet of water per second. The water has been disposed of to the landowners by the sale of water-right contracts, which were made on the basis of 1 cubic foot of water per second for 160 acres, but each right is really for a proportional part of the flow in the canal and is fixed on some specific tract of land. Second-class rights also are sold in like manner, but the right is only to waters possessed by the company in excess of the original appropriation. The cost of a first-class right under the Fresno system is $10 per acre, of a second-class right $5 per acre, and of a right under the Consolidated Canals $4 per acre. The annual rental charge per acre, as fixed by the county supervisors, is 62½ cents under the Fresno system and 75 cents under the Consolidated system. Only water-right contract holders are permitted to use or receive water. Various types of side gates are used, and the ditch tenders rely upon their judgment in estimating the amount of water delivered to each user. The greater part of the water, however, is delivered to party ditches, which usually are incorporated and employ their own ditch tenders who distribute the water. When water is plentiful in the spring, the irrigators have been very extravagant with its use, and as there are

practically no drainage channels through this section, much of the land is greatly in need of drainage.[1]

Fresno County, which is centrally located in the valley and has been more extensively developed than any other section, well represents the possibilities of the valley in agriculture and horticulture. Although it is best known as the home of the raisin, producing more than four-fifths of all the raisins grown in the United States, a wide variety of other fruits and diversified farm products are successful. A large acreage in wine grapes supplies the several large wineries, and numerous packing plants market green and dried products of the table grape, peach, apricot, fig, olive, orange, lemon, pear, plum, nectarine, grapefruit, and pomegranate. Alfalfa for hay and pasture has given dairying a prominent position and is increasing in importance.

The Alta irrigation district, organized in 1888, lies in Tulare, Fresno, and Kings Counties, and comprises an area of 130,000 acres, being all the lands susceptible of irrigation from the Seventy-six Canal. The district purchased the canals and rights of the Seventy-six Land & Water Co. for $440,000, which included the repaying to holders of water-right contracts the amounts which they had paid for such rights.

The original Seventy-six canals and ditches have been extended and others added, until the greater part of the district is now covered. Diversion from the river into the canal regulator is effected by a cement rubble masonry dam 1 foot high, located 1½ miles above the Gould Dam, and is the upper canal on Kings River. A series of angle-iron brackets are embedded in the dam to hold a system of flashboards for diverting water to the Alta canals during October and November when the Fresno canals are closed for repairs and cleaning. The water rights of the Alta canals call for 800 cubic feet per second, but are subject to priorities, and their supply usually ceases during July. During the early months of irrigation there is an abundance of water for all, and the lax regulations permit irrigators to take as much water as they please at any time. Scarcity of water during the dry years brought discontent and dissension among the irrigators, until they refused to vote taxes sufficient to maintain the canal system properly. For several years they voted the least possible amount that would pay the interest on the bonded indebtedness of $492,000 and the salaries of the district officers, without doing any repair work on the canals. The actual cost ran as low as 25 cents per acre per annum, but it did not prove to be cheap water, for the canal system was allowed to deteriorate, until a large sum will be necessary to put the structures and canals in good re-

[1] U. S. Dept. Agr., Office Expt. Stas. Bul., 217.

pair. Much of the land away from the river needs drainage, and the growth of tules and trailing grasses in the canals through such lands has accumulated until only deep, tortuous, and very narrow channels remain, having a very limited carrying capacity. The canals would be ample for all demands if they were kept in repair, and there is a growing sentiment in the district in favor of business methods for conducting district affairs.[1]

In 1909, 80,000 acres were irrigated in Alta district, of which about 20,000 acres were in trees and vines; 10,000 in wheat, barley, and corn; 2,000 in alfalfa; 25,000 in pasture; and 5,000 in gardens and miscellaneous crops. There are 50 miles of mains and 250 miles of laterals in the district. Few of the structures on the system are permanent, and the majority are old timber ones which need replacing.

There is no special method of applying water in the district. The furrow, basin, and flood systems may be seen in neighboring orchards and vineyards, and even in the same orchard in some cases. In the Reedley section of the district, which is well drained by the high river bluff, the greatest demand for water is during the fall and early spring months. This originally was one of the largest wheat-shipping sections in California, but is now in small holdings, on which wine, table, and raisin grapes and peaches are grown extensively, and plums, figs, nectarines, apricots, and oranges are successful, though the acreage is smaller. The growing of melons between the rows of young trees and vines is very popular among the new settlers and is the source of considerable revenue while waiting for the orchard or vineyard to come into bearing. Alfalfa yields four or five cuttings per season when not pastured and is the backbone of the extensive and profitable dairy business in the district, for the greater part of it is consumed locally.

The People's Ditch, the Lemoore Canal, and the Last Chance Ditch are the most important of the canal systems on the lower portion of Kings River. The Lemoore Canal & Irrigation Co. has about 60 miles of ditches, and although it has the earliest right to water of any of the canals on the south side of the river, by agreement with other appropriators its supply is limited to an average of 300 cubic feet per second. It serves about 18,000 acres lying between the other two systems. The head of the canal is about 3½ miles below Kingston, where a low timber weir dam assists diversion. The headworks of the People's Ditch are located about a half mile above the head of Cole Slough. Water formerly was diverted by means of a timber weir dam, but this washed out in the spring of 1909 and a concrete dam is being constructed in the same location. The People's system has about 70 miles of mains and laterals and carries an average of

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 100.

300 cubic feet of water per second and irrigates about 22,500 acres in the vicinity of Hanford. The Last Chance Ditch heads about 6 miles above the Lemoore Canal, but has no permanent diversion dam, depending upon a brush-and-gravel dam during low-water periods. This has to be replaced each season. There are 65 miles of mains and laterals, which carry about 250 cubic feet of water per second.

Conditions are very similar throughout this section. The canals were all built in the early days as cooperative enterprises by the farmers who owned the lands to be irrigated. Work on the ditches was paid for in stock in the company, and while attempts have been made to sell water by measurement, the companies have readopted the original method of apportioning the water according to the ownership of the capital stock and levying assessments to meet current expenses. Only stockholders are entitled to receive water, but where a man has a surplus he is permitted to rent or lease such stock for the season. Irrigation under the latter practice costs from 75 cents to $1.50 per acre per season. Some of the side ditches are incorporated separately and receive their water supply by owning stock in the main canal. The use of water has been very wasteful and a large acreage has been damaged by the resulting high water table. Trailing weed and tule growth are very rapid in these canals, making it necessary to clean them several times during the irrigating season. Willows, which have been permitted to cover the banks of the ditches, interfere with cleaning and increase the seepage losses. Occasionally trees fall into the ditches and obstruct the flow. The Last Chance Ditch banks have been cleared of all willows. The canal structures are of ordinary types. About half the acreage irrigated is in alfalfa and half in trees and vines. Many of the old orchards are not irrigated, because the subirrigated land does not require it, and, in fact, much damage is being done by the high ground-water level.

During the flood season Kings River carries water greatly in excess of the demand of the irrigation systems, and the surplus causes considerable damage by overflowing the delta lands. The greater part of the flood water flows into Tulare Lake and is then beyond further utilization for irrigation. One small reservoir in the Alta district is the only one on Kings River, though there are several excellent sites of large capacity whose service would be of immense value during the later summer months. Any attempt at storage, however, would doubtless precipitate extended litigation.

SAN JOAQUIN RIVER.

The San Joaquin River, which is the main watercourse of the northern part of the valley, has its origin in the high Sierras and receives the run-off of 1,637 square miles. It is the third largest

stream in the valley in volume of water carried at Pollasky, where it debouches upon the open country, and before it reaches Suisun Bay is greatly increased by the flow of nine important streams. From Pollasky it flows southwesterly for 55 miles to the main trough of the valley and then becomes the main drainage artery to the northward for a distance of 120 miles. The San Joaquin and streams to the northward run through deep cuts for many miles after they leave the mountains, and diversion from them is more difficult and expensive than from the streams to the southward, all of which have low banks.

The average monthly flow of the San Joaquin, as computed from measurements at Herndon for the years 1895–1907 and at Pollasky

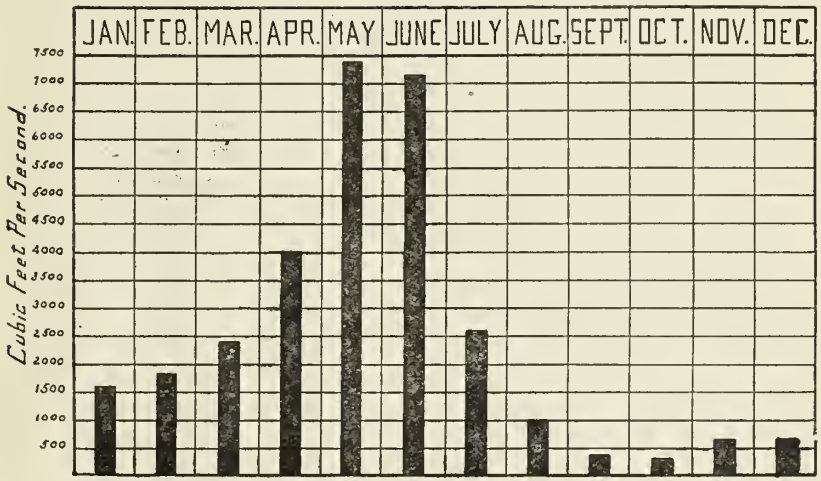

FIG. 6.—Average monthly discharge of San Joaquin River.

for 1908, is shown in figure 6. The average annual flow is 2,526 cubic feet per second. These records were taken at a point where the river leaves the mountains and before the flow is added to by the other streams. The greatest flow is during May and June, while from September to December, inclusive, the river is at low stage. Unusual flood periods sometimes occur in the early spring, the greatest of which in recent years was on March 19, 1907, when the run-off from the entire northern section of the San Joaquin Valley drainage basin is estimated to have aggregated 313,000 cubic feet per second. The average for the four days from March 18 to 21 of the same year was about 227,000 cubic feet per second.

The east side of the valley has reached little development from San Joaquin River waters, the principal use having been for flooding large landholdings devoted to wild-grass pasture. Stock raising has been prominent in this section for years, but a large tract is now

being subdivided for settlement. The several canals take practically all of the normal flow of the river, but there is much room for improvement by extending the acreage under permanent crops and obtaining greater benefit from the irrigation water. The Aliso, Blythe, and Chowchilla Canals, on the east bank of the river, are used principally to water pasture lands owned by Miller & Lux and the California Pastoral Co., but in addition irrigate about 5,000 acres of alfalfa and grain.

Farther down on the same side of the river is the East Side Canal, which has its head about 14 miles southwest of Merced, and follows a northerly course for about 20 miles to the Merced River. It commands an area of about 50,000 acres, but irrigates only 1,300 acres of alfalfa and some pasture. The canal originally was built for stock purposes, but has been enlarged and converted into an irrigation canal and has secured a court decree to 760 cubic feet per second flow, although with the slight grade and present weed growth it would not carry that quantity. Ten thousand acres in the Stevenson ranch are irrigated from the East Side Canal, and in addition 10,000 acres of colony lands, together with water rights, are being sold.

The James Canals, of which there are three, are the upper canals on the west side of the river, although they really receive their water from the Fresno Slough. They have an aggregate length of about 35 miles, and during some seasons irrigate 15,000 acres, most of which is pasture. Development has been prevented by an injunction which has forbidden the diversion of water by these canals during the past 10 years, but in 1909 a decision of the supreme court of California granted them the right to a considerable flow. Extension and improvement of this system are planed for the near future.

The most important and largest canal system on the San Joaquin River is the San Joaquin & Kings River Canal & Irrigation Co., started in 1872. Its head is below Mendota, where diversion is effected by means of a timber dam 10 feet high and 300 feet long, with a system of flashboards. The main canal and principal laterals have an aggregate length of about 200 miles, an average grade of 1 foot per mile, and a carrying capacity of 1,400 cubic feet per second. The company has a right to 760 cubic feet per second, but it usually carries a much larger amount, including water for Miller & Lux lands, which have an indefinite riparian right. In the late summer there is often an insufficient flow in the river to furnish the full amount for the canal. About 100,000 acres are irrigated from this system, of which 70,000 are in alfalfa and the remainder in grain. Dairying and cattle raising are the principal industries, and very few trees and vines are grown. About 15,000 acres of wild-grass pasture is flooded from the canals and about 50,000 from the river, in addi-

tion to the 100,000 acres in alfalfa and grain. The bulk of this "swamp irrigation," as it is called, is for the purpose of alkali reclamation on lands that are adjacent to the river, and the damaging salts are leached from the soil by the water, which flows at a depth of 1 to 5 feet between check levees, located one-fourth to 1 mile apart. The land to be reclaimed is flooded only about two months a year, owing to the scarcity of water, but the operation is repeated for several years until the land is rendered productive. During the process the land furnishes much wild feed for cattle.

Trailing grasses and tule growth in the canals give much bother, and it is necessary to drag them with a chain each season, and to scrape and clean them thoroughly every 10 years, at an average cost of $500 per mile. A constant warfare is waged against ground squirrels and gophers, which damage crops and cause breaks in the ditch banks.

Water is delivered by means of measuring weirs at the heads of the lateral ditches, the small laterals being controlled by the farmers whose lands they serve. Up to and including the season of 1907 water was charged for by the acreage irrigated, regardless of the crop and quantity used. The rates per acre as fixed by the county supervisors were 85 cents in Fresno County, $1.65 in Merced County, and $1.50 in Stanislaus County. The courts in 1908, however, permitted the canal company to change the basis of charges to the cubic foot per second flowing for 24 hours, and the rates as fixed by the company were $1.10 per cubic foot per second flowing for 24 hours in Fresno County, $1.75 in Merced County, and $2.25 in Stanislaus County. Former practice has been to irrigate alfalfa to an approximate depth of 2½ feet per season, and the above charge for water was estimated from that standpoint. It is a significant fact that the canal company proposes to increase the rates, because the irrigators are using much less water per acre since they have to pay for the actual amount delivered to them, and the revenue to the company accordingly is diminished. Although the irrigators are now using all the water they need, there is an incentive for economical use of water. A greater number of field laterals is being constructed so the wasteful practice of running water through several checks can be eliminated, and the tendency of irrigating too many times during the season in order to force crops by irrigation rather than by working the soil is being abandoned also.

The water table has risen all through this section since irrigation has been practiced and is now 5 to 8 feet from the surface. It is much nearer in some localities, and is still rising. The serious mistake of filling the natural drainage channels was made when settling the land, as there is little fall to the surface. Some attention is now

being paid to proper drainage, but there is an imperative need for extensive efforts in this connection.

The Patterson ranch, consisting of 19,000 acres, lying north of the lands irrigated by the San Joaquin & Kings River Irrigation Co.'s canals, on the west side of the San Joaquin River, in Stanislaus County, has been provided with a very carefully planned and well-constructed irrigation system. An electrically driven pumping station, with a capacity of 110 cubic feet per second, is located on the bank of the San Joaquin River. The land has a fall of about 17 feet to the mile, and the tract is divided into five zones, each supplied by separate laterals and having a pumping plant to lift the water to the next higher. There are about 50 miles of main and lateral canals, all cement lined. Construction was started in the spring of 1909, and some irrigating was done under the system during the summer of 1910. The first unit of 4,000 acres has been placed on sale.

After the irrigation system had been constructed by the Patterson Land Co. at a cost of $169,000 it was transferred to the Patterson Water Co. A share of stock in the water company is sold with each acre of land, but until 75 per cent of the land is disposed of the company will handle the business by proxy; after that time the landowners will handle it themselves. A share of stock entitles the holder to not less than 2 or more than 3 acre-feet of water per annum. The shareholder must pay $3 per annum for the 2 acre-feet, whether or not he uses the water. He may elect whether or not he will take the extra acre-foot, but if he does he must pay $1.50 for it.

The first pumping station is on the bank of the river, where two concrete tunnels, 4 by 6 feet, running side by side, conduct the water from the bottom of the river to a circular sump or well 25 feet in diameter. From this the water is pumped into the main canal by four 20-inch centrifugal pumps, each operated by a 100-horsepower motor, the maximum lift being 21 feet. The water flows in the main canal for a distance of 1 mile and is then lifted 13 feet by a battery of three 20-inch pumps, operated by 50-horsepower motors, and one 15-inch pump operated by a 30-horsepower motor. It is again carried three-fourths mile by canal and then lifted 11 feet by three 20-inch pumps. Three-fourths mile farther there is another pumping plant of two 20-inch and one 15-inch pump, and five-eighths mile farther the water is lifted to the last lateral by two 15-inch pumps. Several laterals are taken out of the main canal, which accounts for the diminished size of each succeeding pumping station. To avoid the peak load on the power line, the plant was designed to be operated only 19 hours per day. In order to allow a continuous flow in the canals four concrete-lined reservoirs were constructed for the purpose of holding the water pumped from one station to the next.

The first has a capacity of 2,030,000 gallons; the second, 1,450,000; the third, 1,030,000; and the fourth, 590,000 gallons.

All of the pumping units are not in operation, because the present irrigated acreage does not require the full capacity.

MARIPOSA CREEK.

Mariposa Creek is the smallest stream in the San Joaquin Valley on which measurements have been kept. This creek has a drainage area of 122 square miles in the foothills of the Sierras and flows westerly through Merced County. The monthly discharge, as shown in figure 7, is the average of measurements at the base of the foothills from 1879 to 1883, inclusive. The average annual flow is 46 cubic

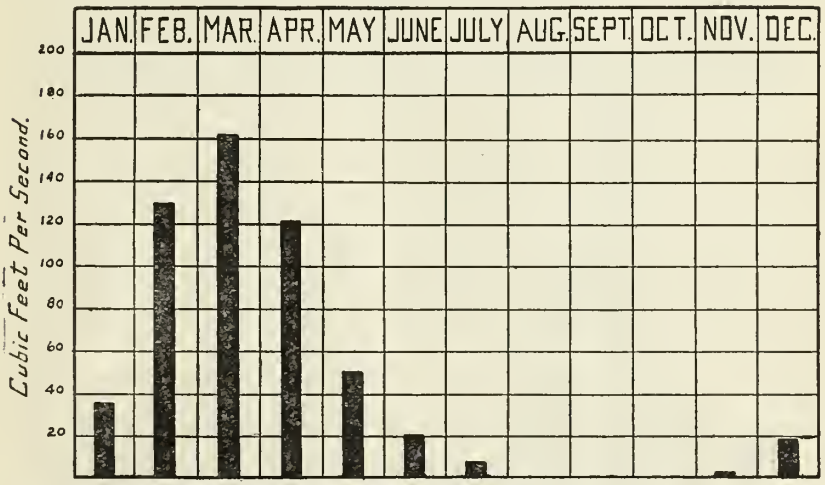

FIG. 7.—Average monthly discharge of Mariposa Creek.

feet per second, but the bulk of the run-off occurs from March to April. Little use is made of the water other than to flood wild grasses near the San Joaquin River. No storage is practiced.

CHOWCHILLA CREEK.

Chowchilla Creek receives the run-off from 268 square miles of foothill and low Sierra watershed, and is very similar to the Fresno River in origin, size, and flow. Intermittent floods occur during March and April, and from June to November, inclusive, the stream is dry, as shown in figure 8, which gives the average monthly flow at the base of the foothills from 1879 to 1883, inclusive. The Bliss and the Miniturn, or Sierra Vista Vineyard, Ditches are the only irrigation systems on the Chowchilla. Simple earthen dams in the stream bed divert water into the canals, which irrigate about 6,000 acres of

vines, alfalfa, and grain. There are good reservoir sites in the foothills, the Buchanan reservoir site having an estimated capacity of 42,000 acre-feet, but nothing has been done to use them. The water of Chowchilla Creek should irrigate 30,000 acres if the total discharge were made available by storage.

FRESNO RIVER.

The Fresno River is a torrential stream flowing through Madera County and draining an area of 272 square miles in the foothills and low sierras. The flow of the Fresno is intermittent, being dependent upon the rainfall for its water supply, and large flood periods are of short duration. It will be seen by figure 9, which represents the average monthly flow for the years 1879–1883, inclusive, that the

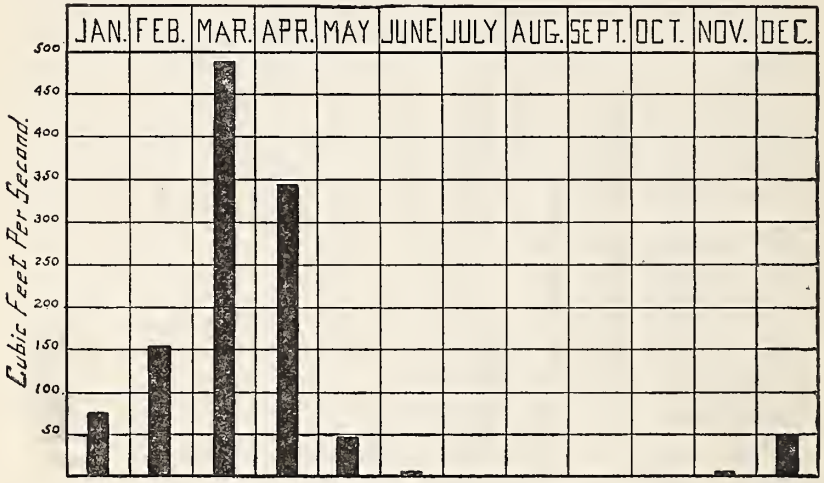

FIG. 8.—Average monthly discharge of Chowchilla Creek.

principal flow occurs during March and April, while from June to November, inclusive, the bed of the stream is practically dry. The average annual flow is 118 cubic feet per second.

The principal diversion from the Fresno River is that of the Madera Canal & Irrigation Co., which has a first right to 250 cubic feet per second in addition to about 4 cubic feet per second that it receives from a flume that carries lumber from the mountains to the town of Madera. Rock-fill dams divert the flow of the river into Adobe Slough to avoid the excessive losses by seepage and evaporation in the wide, sandy bed of the main stream, and the canal has its head about 2 miles above Madera. About 20 miles of mains and main laterals cover about 40,000 acres to the south and southwest of town, but only 16,000 acres is under irrigation, and during dry years a much

less acreage can be served. Water-right contracts have been sold on about 8,000 acres at $5 per acre, with an annual rental charge of $1 per acre. The county supervisors have fixed the charge for irrigating other lands at $1.30 for the first irrigation and 50 cents for each subsequent irrigation. Five thousand acres of alfalfa, 3,000 of vines, 1,000 of orchard, and 7,000 acres of grain are irrigated.

A recent court decision prevents the Madera Canal Co. from storing water from the Fresno River, and further advancement is thereby blocked. If the entire flow of the stream could be utilized a far greater acreage than at present could be irrigated. There are several small reservoir sites on the east side of the river between Madera and the foothills, and the canal company owns some of them having an aggregate capacity of 5,000 acre-feet. The decision of the courts prohibiting the impounding of water was secured by riparian owners

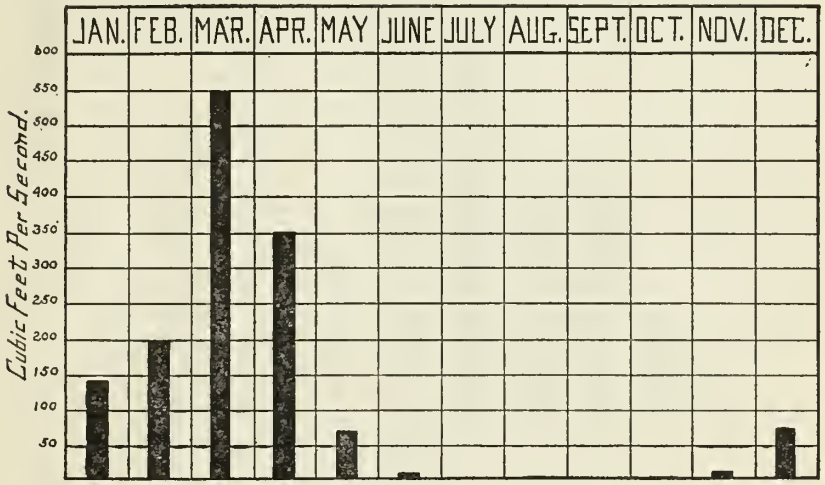

FIG. 9.—Average monthly discharge of Fresno River.

in the bottom lands along the San Joaquin River, who want the flood water of the Fresno River for the purpose of flooding wild-grass pasture. The basis of the decision was that a riparian owner is entitled to have the normal flow of the river reach his lands, and for the same reason there can be no flood-water flow of a stream. If this case is taken as a precedent, the conservation of excess waters will not be permitted, and the greatest avenue for a more complete development of the arid lands of the State will be closed.

MERCED RIVER.

The Merced River is the fifth largest stream in the San Joaquin Valley, and its upper reaches are famed for their scenic beauty, as evidenced by Yosemite National Park, through which it flows. It

receives the run-off from 1,090 square miles of watershed, a part of which is in the high Sierras. It differs from the other streams in the northern part of the valley by having a secondary valley several miles wide near Snelling.

The average monthly flow of the Merced River above Merced Falls for a period of seven years, 1902–1908, is shown in figure 10, and the average annual flow is 1,665 cubic feet per second. The principal discharge is from March to June, inclusive, with a moderate flow during July and a minimum flow from August to December.

The Crocker-Huffman Land & Water Co. owns the only large canal system diverting water from the Merced River. It is an enlargement and extension of the Farmers' Canal, which was started in 1872, but

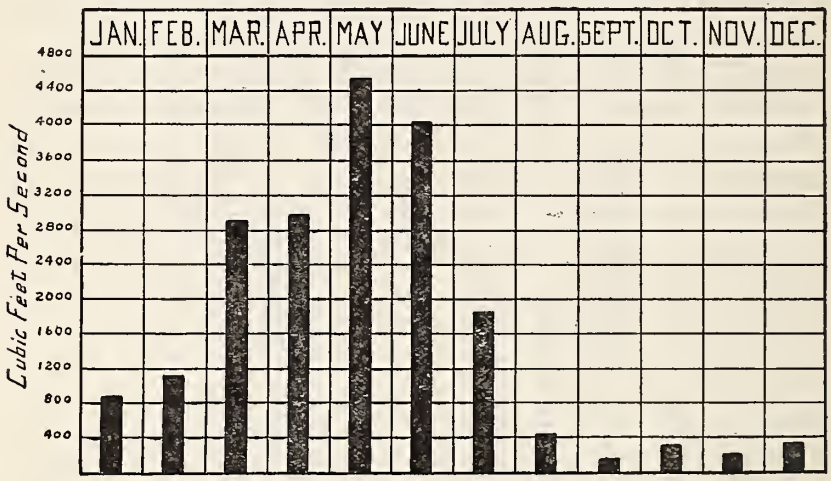

FIG. 10.—Average monthly discharge of Merced River.

met with financial shortage, due to encountering construction difficulties. The canal heads about 2 miles below Merced Falls at a simple weir dam built of brush, rock, and cribbing, with a length of over 250 feet and a height of 21 feet. The upper part of the canal has a bed width of 80 feet, and was planned to have a depth of 10 feet to give it a carrying capacity of 1,500 cubic feet per second, but its actual capacity is much less. There are two tunnels, 1,700 and 2,100 feet long, respectively, having a width of 22 feet and a height of 10 feet, the longer being timbered throughout. The main canal has a fall of 1 foot per mile and the upper portion is excavated in sand and gravel, which permits heavy seepage losses. Just below the first tunnel the water is divided, part going into a natural creek channel that is utilized to carry the water supply for lands around Atwater and Livingston, while the main canal continues to a storage

reservoir in the low foothills 5 miles northeast of the town of Merced. This reservoir, known as Lake Yosemite, covers nearly 600 acres and has a capacity of 15,000 acre-feet. It furnishes the water supply for the city of Merced in addition to irrigation water for the land east of Merced. Storage is effected by a dam having a length of 2,200 feet on the crest and a maximum height of 50 feet.

The main canal has a length of 21 miles from the headworks to Lake Yosemite, and the principal laterals have an aggregate length of 250 miles. Although the demand for irrigation water under this system has not thus far exceeded its capacity, it is probable that extensive settlement in the future will render it inadequate. The location of the main canal could have been easily improved upon, and the practice of converting natural drainage channels into carrying canals for irrigation water has not proved entirely successful.

The general use of water under the Crocker-Huffman system is wasteful. Water-right contracts are sold for $10 per acre, on the basis of 1 cubic foot per second for 160 acres, and the annual charge is $1 per acre. Irrigation from the canals is permitted only on the lands holding the above contracts, but there is little regulation of the use of water. There is but little night irrigation thus far. An irrigator is permitted to take all the water he wants and whenever he wants it, except in times of shortage, when the apportioning of the flow in the canal is left to the judgment of the ditch tender. A large part of the land does not need irrigation, and in low depressions in the land are ponds of water. No effort has been extended toward relieving this condition by drainage, and therefore the demand for water for irrigation under this canal is not in proportion to the land cultivated. Water is not used on some of the land provided with water rights for the above reasons, and it is difficult, therefore, to estimate the acreage irrigated from the Crocker-Huffman system, although it probably does not exceed 20,000 acres exclusive of wild pasture lands. The principal crops irrigated are sweet potatoes, alfalfa, vines, and peach trees. The light, sandy soil around Atwater and Livingston is well adapted to growing sweet potatoes and yields as high as 250 sacks per acre. It often is unnecessary to irrigate trees and vines and alfalfa. Dairying is not extensively practiced in this locality, and the bulk of the alfalfa is either baled and shipped or pastured by beef cattle.

The development of Merced County has been retarded greatly because much of the land around Merced is quite rich and rather heavy and has returned a fair profit from grain raising. As long as the owner can farm on an extensive scale and reap a good return he will not sell, and it is a significant fact that the city of Merced is practically hemmed in on three sides by large holdings of this nature.

These lands in time will be subdivided and placed under intensive cultivation with irrigation. The almost inexhaustible supply of underground water and occurrence of an artesian flow have caused several pumping plants to be installed in this section for irrigation.

There is considerable irrigating along the Merced River between Merced Falls and Livingston by several small ditches diverting from the river. These ditches are of particular interest, because they are among the first irrigation projects in the State, some having been started in 1859. Alfalfa and corn are the main crops, although some old orchards under these ditches have prospered.

TUOLUMNE RIVER.

The Tuolumne River is the largest stream in the San Joaquin Valley, receiving the run-off from 1,500 square miles of Sierra watershed,

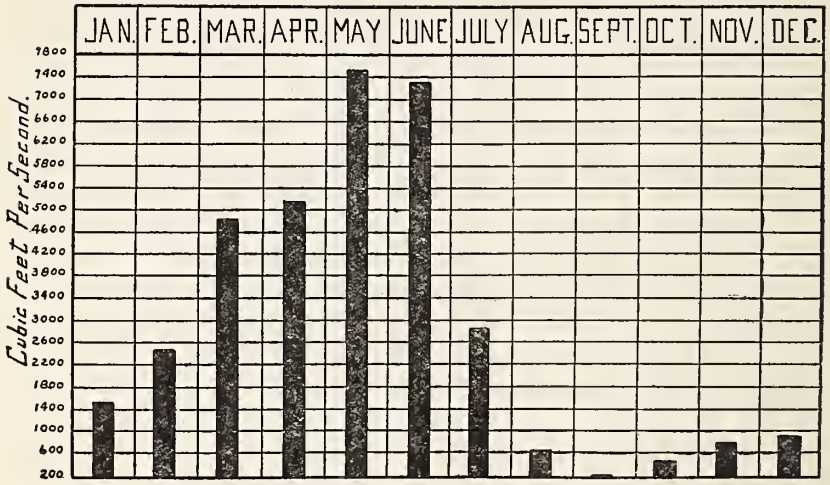

FIG. 11.—Average monthly discharge of Tuolumne River.

and its branches reach into territory of great public interest, such as Yosemite Valley, Hetch Hetchy Valley, and Lake Eleanor. The average monthly flow at La Grange for a period of 13 years, 1896–1908, is shown in figure 11. The average annual flow is 2,926 cubic feet per second. The high spring flow occurs from March to June, while from August to December it is a minimum. Irrigation from the Tuolumne is confined to the Modesto and Turlock irrigation districts, which, although separate organizations, have interests in common. They are joint owners in the immense diverting dam at La Grange, have similar soil and climate, are subject to the same laws and regulations, and since their inception in 1888 have met substantially the same litigation and accompanying difficulties. The

Modesto district comprises 81,143 acres in Stanislaus County on the north bank of the Tuolumne, and Turlock district comprises 176,210 acres on the south side of that river in Stanislaus and Merced Counties.

The width and deep cut of the river made it necessary to place the diverting dam at La Grange, 22 miles above the head of the districts. This dam, which is of uncoursed rubble masonry laid in cement concrete, has a height of 126 feet, and at the time of construction was the highest overflow dam in the United States. Its cost was $546,000. The Modesto Canal heads on the north end of the dam and the Turlock Canal on the south end, the first 600 feet of the latter being through a solid rock tunnel. The first 5 miles of both canals are through rough foothills country, where heavy cuts and fills and expensive canal structures are encountered, followed by the open foothills until the main plains of the San Joaquin Valley are reached 15 miles west of La Grange. Near the head of the district the Turlock Canal divides into two mains, one of which runs south to within 5 miles of the Merced River, a distance of 11 miles, and the other branch continues west to within 1.5 miles of Ceres, where it turns south, a total length of 14 miles. The aggregate length of mains and main laterals is 147 miles in the Turlock district and 130 miles in the Modesto district. Eleven flumes in the upper portion of the Modesto main canal have an aggregate length of more than a mile. The headworks of both canals are of concrete, and as rapidly as the original wooden drops, spillways, and other canal structures become unsafe they are being replaced with permanent reenforced concrete. Concrete lining also has been placed in several thousand feet of the main canals to prevent excessive seepage loss and to render them safe.

Competent engineers are in charge of the operation and maintenance of the canals, under the direction of boards of directors, and their policy of improving the canals and increasing their capacity in advance of the demand for water gives satisfaction. Turlock Canal was designed to carry 1,500 cubic feet per second of water and the Modesto Canal to carry 640 cubic feet per second, but as yet neither of them has accommodated so large a flow. These canal systems are in fairly good condition throughout and have not been bothered with aquatic growths to any great extent.

Water is shut off usually during September or October, when there is the least demand for it, and the cleaning of ditches, repairing of structures, and new construction work are then commenced, in order that the systems may be placed in good shape for the next season. Water is again turned in the canals about the first of the year, and, except through accident, is run continuously until the end of the irrigating season. Very few practice winter irrigation in the true sense

of the term, but a considerable number apply water to their land during the winter months for the purpose of killing gophers or settling new land that is being leveled for planting. A full head of water usually is demanded during April and continues throughout the season, or until the supply in the river becomes insufficient to fill the canals.

The distribution of water is in charge of 16 ditch tenders in Turlock district and 15 in Modesto district. The length of canal under each man's care varies from 6 to 10 miles, and the area irrigated under each man's beat varies from 1,000 to 3,500 acres. Both districts have private telephone lines extending over the greater part of their systems, which permit ditch tenders to communicate with the offices promptly. Another commendable feature is the converting of main canal banks into roadways, which has been done at a very slight cost and allows the ditch tenders to drive along the ditches and inspect them very closely.

It has become necessary, as the irrigated acreage increased, to formulate rules and regulations governing the use and distribution from the canals, in order that all might share alike. The rules of the two districts are essentially the same, and a résumé of some of the more essential rules of Modesto district follows:

Water is supplied to the irrigators by rotation, commencing at the upper end of each lateral ditch. The irrigator is allowed a certain "head" of water, the size of which varies with the crop, for a definite length of time for each acre to be watered. If the irrigation is not completed within the time limit, the water is passed on to the next in turn. This is equivalent to fixing a maximum duty of water for each crop, and compels the farmer properly to prepare his land and ditches for self-protection. Irrigation must be prosecuted day and night, and the refusal of an irrigator to take the water when his turn comes is counted as equivalent to an irrigation and is passed to the next in turn. All diverting gates are under the direction of the district. No trees or vines or alfalfa are allowed to be grown on the district canal banks. Special permission must be obtained from the superintendent before placing any opening or structure in the district canal banks. In case of shortage of water preference is given to garden crops and first-year trees and vines. The ditch tenders report by telephone to the superintendent every day.

The average maximum flow of the Modesto Canal during the height of the irrigating season of 1909 was about 550 cubic feet per second and of the Turlock Canal about 900 cubic feet per second. The total amount of water diverted during the season was 151,600 acre-feet for Modesto district and 233,600 acre-feet for Turlock district. This would give a depth of 6.9 feet of water over the 22,136 acres irrigated in Modesto district, and a depth of 4.5 feet over the

51,937 acres irrigated in Turlock district, but as these measurements were taken at the head gates of the canals an allowance must be made for the losses due to seepage and evaporation, and during the early spring months, before the demand for water was great, a considerable amount passed over the wasteways at the terminals of the canals.

It will be seen from figure 11, page 48, that the average flow of the Tuolumne River after the latter part of July falls before the demand of the two districts, but the spring flow is far in excess. One day in June, 1907, the flow was 55,000 cubic feet per second, or in 24 hours enough water passed over the dam to meet more than one-fourth the annual demand of the combined districts, but the minimum flow, which occurred in September, 1898, was less than one-fiftieth of the daily demand during September. The Modesto district is constructing a storage reservoir with a capacity of 30,000 acre-feet in order to insure against a shortage of water for irrigating during the latter part of the summer. The cost of this reservoir will be about $250,000. It is located in the foothills between the dam and the head of the district and is so arranged that it will be filled by the surplus flow of the canal during the spring months, when the demand for irrigation is light. There are also several excellent storage sites on the upper Tuolumne River, in the higher mountains, which may be used as needed.

Taxes are levied on an assessed valuation of property within the districts to meet the interest on bonds issued for the construction of the irrigation systems and to meet the annual operating and maintenance expenses. The total tax amounts to approximately $1 per acre per annum, and the land is taxed whether it is irrigated or not. A small expense has been necessary also to provide drainage for lands on the lower side of the districts near the San Joaquin River, where the underground waters, owing to irrigation and lack of natural drainage, had risen to a damaging height. The extent and methods of this drainage work are given in a bulletin of this office.[1]

The crop acreage in Modesto and Turlock districts in 1909 is shown in the following table:

Crop acreage in Modesto and Turlock districts in 1909.

Crop.	Modesto district.	Turlock district.	Crop.	Modesto district.	Turlock. district.
	Acres.	*Acres.*		*Acres.*	*Acres.*
Alfalfa	16,306	29,920	Cabbage	.....	5
Vines	2,404	5,216	Tomatoes	9	3
Orchard	2,298	5,797	Berries	.....	22
Sweet potatoes	34	3,554	Nursery stock	.....	78
Potatoes	.....	22	Pumpkins	.....	43
Corn	561	3,038	Cantaloup	.....	25
Beans	108	238	Oats	6	2,145
Artichokes	.....	1	Millet	17	.....
Garden	393	1,450			
Melons	.....	380	Total	22,136	51,937

[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 217.

STANISLAUS RIVER.

The Stanislaus River has a drainage area of 1,000 square miles, with its source in the high Sierras. A branch of the river is the dividing line between Calaveras and Tuolumne Counties, and in the valley floor a portion of the boundary between Stanislaus and San Joaquin Counties is formed by the main river. On the headwaters are located immense power plants that furnish electric energy to the mines in that section and to several cities in the lower valleys.

Ditches built originally for mining purposes are now used for irrigation in the mountain valleys, especially around Sonora, and while the irrigated area is not large, the people are turning to agriculture, and new settlers are extending the practice.

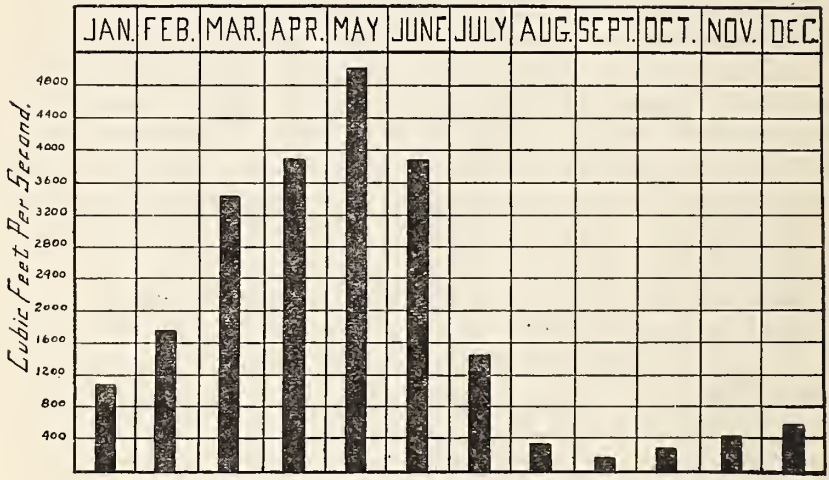

FIG. 12.—Average monthly discharge of Stanislaus River.

The Stanislaus River is the fourth largest stream in the San Joaquin Valley, having a mean annual discharge of 1,873 cubic feet per second. The greatest monthly flow occurs from March to June, and the minimum is from August to December, inclusive, as shown in figure 12, which represents the average of the measurements taken at Knights Ferry for the years 1896–1900 and at Oakdale from 1904–1908, inclusive.

The Stanislaus Power & Irrigation Co. owns the only canal system receiving water from the Stanislaus River for use in the San Joaquin Valley. The headworks are located 6 miles above Knights Ferry, at the same point where a wooden dam was built in 1855 to divert water for hydraulic mining about 7 miles distant. Subsequently, Judge Schell planted a large orchard and vineyard in a foothill valley near Knights Ferry and irrigated it from this ditch. The Farmington Water Co. was incorporated in 1874 and began the construction of a

more extensive canal system to serve the lower valley lands, but after a few years the company was forced to abandon the project owing to the lack of interest shown by the landowners, who were engaged exclusively in grain raising. The fertility of the soil was such at that early date that profitable crops could be secured three years out of five without irrigation. The farmers in 1888 organized the San Joaquin Land & Water Co. to develop the irrigation project, as grain growing had ceased to be a bonanza. This and a succeeding company failed, and in 1894 the Stanislaus & San Joaquin Water Co. acquired the rights of the old San Joaquin Water Co. and constructed a canal system, using the old Schell dam and a portion of the ditch. About 60 miles of ditch, 2 miles of flume, some tunnel, and the foundation for a new dam 4,000 feet below the old site had been completed in 1895. Water-right contracts, at a cost of $10 per acre and an annual rental of $1.50 per acre, were issued to the landowners, and work on the canal system was apparently progressing nicely when the company failed in 1896, and a receiver managed the system for two years. It was then bought at auction by the creditors, who pooled their claims and later sold to the present owners, who have made a few extensions and improvements in the ditches. In 1892 a dam was constructed by a company composed of landowners on the south side of the Stanislaus, around Oakdale, and a ditch was built up to within a mile of Oakdale, but the first freshet washed the dam out. It was rebuilt the following year without engineering advice, as was the first one, and after a few weeks of irrigation this dam washed out. Outside capital then organized the Oakdale Irrigation Co., bought the old ditches, and arranged to receive a water supply from the canals across the river. Stock in the old company was exchanged for water-right contracts valued at $20 per acre, and the annual charge for water was fixed at $1.50 per acre. The water-right contracts were not issued for special lands, being recognized merely as a right to receive water from the ditches, and therefore were a source of speculation among farmers and merchants alike. These contracts were eventually disregarded and water was delivered for various amounts, usually $3 per acre per year.

A wooden flume was built on the county bridge to connect the two ditch systems, but two or three years later fire destroyed bridge and flume, whereupon two 18-inch steel pipes were placed on the new bridge to carry the irrigation water. The collapse of the abutment to this bridge in 1907 caused one of the pipes to be abandoned, and now the entire supply for irrigation around Oakdale is sent through one pipe.

The service grew worse, and in 1906 a receiver was appointed, who sold the ditches to the owners of the system across the river. The

combined system was then operated on a rental basis, but several different rates were charged, depending upon soil, crop, and water-right contracts. The laterals are small, and each irrigator is allowed the entire flow until he has completed an irrigation, then it is passed to the next one. There are 118 miles of main and lateral ditches in the system, and the actual quantity of water carried does not exceed 150 cubic feet per second. The system covers 20,000 acres, of which about 4,000 are irrigated.

The service has not been satisfactory because of small ditches and lack of improvement in general, and for the purpose of relieving this condition two irrigation districts were organized under the State law in the summer of 1909. The owners of about 71,000 acres in the vicinity of Escalon, Ripon, and Manteca organized the South San Joaquin irrigation district, and declared in favor of a system that would include complete provisions for drainage of the lands now being damaged by the high ground-water table and the prevention of a spread of such damage to other lands. After preliminary surveys had been completed, bonds to the extent of $1,875,000 were voted to provide a good and complete irrigation and drainage system. The owners of about 65,000 acres in Stanislaus and San Joaquin Counties in the vicinity of Oakdale organized the Oakdale irrigation district and voted $1,600,000 in bonds for the construction of an adequate irrigation system. The two districts have purchased the water rights and canal system of the Stanislaus Water Co. for $650,000, which includes the water rights of the power plant at Knights Ferry. Plans are nearing completion for the construction of a dam 80 feet high in the Stanislaus River about 4 miles above Knights Ferry, and for the construction of 8 miles of main canal, with a carrying capacity of 1,700 cubic feet per second. By agreement between the two districts the cost of water rights and construction of the dam and headworks will be joint expense, and the water will be divided equally. Plans for the South San Joaquin district also include a foothill reservoir about 3 miles northeast of Thalheim, to hold about 75,000 acre-feet of water, at an estimated construction cost of $375,000. Laterals will be built to each 40-acre tract in the district, and control of all canals and laterals will therefore be in the hands of the district officers. Where feasible the old ditches will be included in the cross section of the new canals, but no attempt is being made to patch up the old system. At least two years will be required for the construction of the new canals and ditches, and in the meantime the old system will be operated on a toll basis for the irrigation of as large an acreage as the canal flow will permit.

The extravagance with which the limited supply of water for irrigation has been used in this section has allowed only a comparatively

small acreage to be developed, and a portion of that is now in need of drainage. The installation of an adequate canal system, with storage reservoirs, as proposed by the new districts, will bring a great development.

CALAVERAS RIVER.

The Calaveras River has a drainage area of 106 miles in the low Sierras and foothills, and is intermittent in flow. It is known principally for the damage it has caused to the city of Stockton and environs by sudden spring floods. The river divides about 17 miles northeast of Stockton, a part of the water flowing into a branch called Mormon Slough, which goes through Stockton, while the Calaveras Channel passes about 2 miles to the north. A diverting

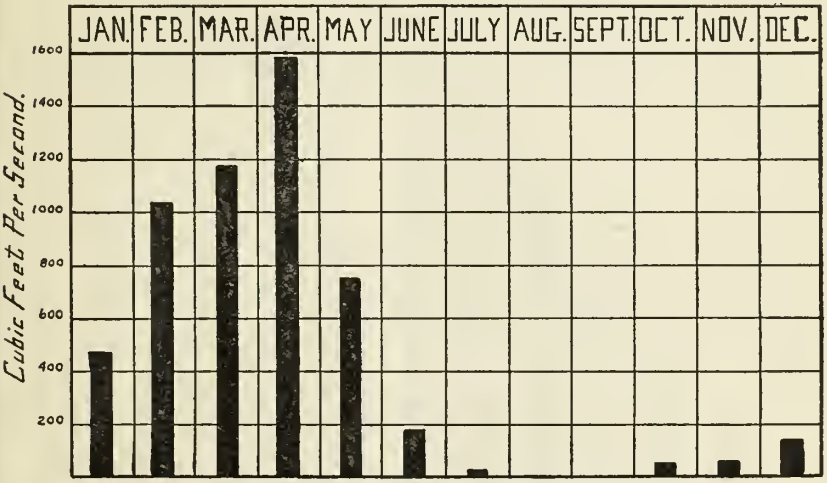

FIG. 13.—Average monthly discharge of Calaveras River.

canal is being constructed near Stockton from Mormon Slough to the Calaveras Channel, which will give partial relief from floods and prevent the lower portion of Mormon Slough from filling with silt.

The average monthly flow, computed from measurements at Bellota for 1879–1884, and at Jenny Lind for 1908, is shown in figure 13. The average annual discharge is 458 cubic feet per second, but from July to November, inclusive, the flow is very small. Sudden flood periods are caused by rains from February to May, but they usually are of short duration.

Although it traverses a section that would be benefited by irrigation, no present use is being made of the water of the Calaveras. However, plans are being considered for a storage reservoir in the foothills that will prevent floods and furnish a water supply for irrigation purposes.

MOKELUMNE RIVER.

The Mokelumne River has a drainage area of 537 square miles. Measurements were made at Electra in 1904 and at Clements from 1905 to 1908, and the average monthly discharge is shown in figure 14. The average annual flow is 1,523 cubic feet per second, placing it as sixth among the streams of the valley. Its comparatively large discharge from March to July is due to the source being in the high Sierras.

The Stockton Mokelumne Canal Co. owns the only system diverting water from the Mokelumne River, and as there is no competition the company claims control of the entire flow of the river. The history of this canal system is filled with difficulties and failures. An incorporated company built a rock and crib dam in the Mokelumne

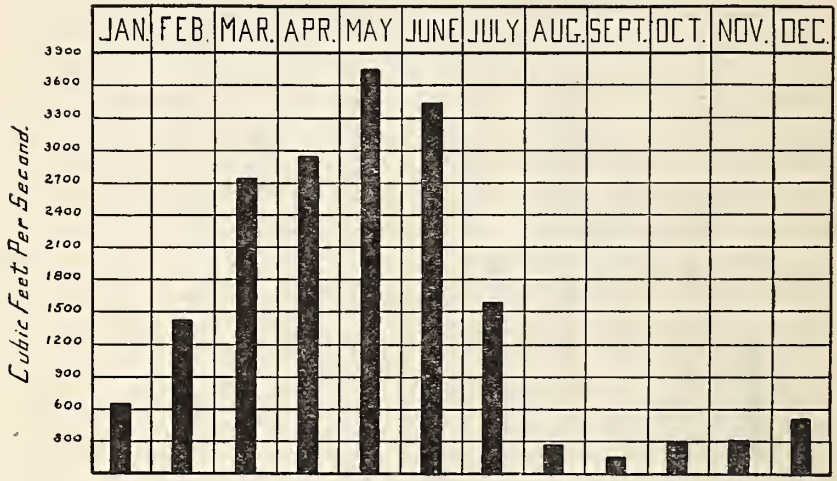

FIG. 14.—Average monthly discharge of Mokelumne River.

at Woodbridge in 1887, and in order to hasten the work on the canal leading toward Stockton the landowners along the route built a large part of the canal with their teams and received time checks in payment. Water-right contracts were sold in the canal system for $20 per acre, with an annual rental charge of $1.50 per acre. The dam had no foundation, and consequently the water undermined it and made a great hole. Within three years the company became bankrupt and a receiver was appointed. The bondholders instituted a suit to recover their money, but lost it. The receiver made improvements without authority and repaired the dam without having engineering advice. Shortly afterwards the entire dam washed out, and the system was sold at auction for $21,000, or less than one-fourth the original cost. The purchasing company attempted to supply water for the canals by pumping from the river with a 300-

horsepower engine and a 36-inch centrifugal pump, but this was unsuccessful. A timber dam backed with a rockfill was then put in at a cost of $25,000 about 300 feet below the old dam site, and is in use at present. Three or four years afterwards this company sold the system to a new company, and still another company secured it after a few years. It changed hands again the first of this year, 1910, and the present owners of the Stockton-Mokelumne Canal system intend to improve it.

The old water rights that were sold by the original company were dissolved, and the time checks which had circulated in place of money among the farmers and merchants during hard times also were declared worthless. The loss, which amounted to quite a sum, involved many who were in no manner interested in irrigation. The company now claims an appropriation of 800 cubic feet per second from the Mokelumne and also all the riparian rights on the river, these having been purchased by an earlier company. The maximum capacity of the main canal is 750 cubic feet per second, but it divides into three laterals about 1 mile from the headworks. There are 45 miles of mains and laterals. These run in straight lines and often follow section and subdivision lines. Approximately 32,000 acres are under ditch, but the area actually irrigated is confined to a narrow strip and does not exceed 3,200 acres. The average flow in the canals is about 150 cubic feet per second. The headworks of the system are well within the valley, and there is an immense area of land to the east that can not be irrigated from the canals. The water level is within the range of root penetration on the lowland. This fact, together with the uncertainty in the past of receiving water from the channel, has discouraged irrigation in the district. There is no doubt but that irrigation would be profitable and the demand for water is increasing.

Irrigators are furnished water at the following rates: For alfalfa, $2.50 per acre per season; for grain, $1 per acre per irrigation, but one irrigation being used; for trees and vines, 75 cents per acre per irrigation up to June 15, and $1 per acre per irrigation after that date. The distribution of the water is in charge of a superintendent and a ditch tender. The canals in general are clean, but tule growth is becoming troublesome in the smaller laterals. All of the land that is irrigated under the system is less than 40 feet above tidewater and has a general slope which permits 6 to 8 acres to be included in an alfalfa check. Much water, however, is wasted in such large checks, and they are being reduced in size. Five cuttings of alfalfa are secured each season, and the general practice has been to give as many as eight irrigations, but this also is a needless waste. Inability to secure water when desired has caused many farmers to install pumping plants, there being over 600 of such plants in San Joaquin County.

COSUMNES RIVER.

The Cosumnes River is the northernmost of the San Joaquin Valley streams and usually is considered to be the dividing line between the Sacramento and San Joaquin Valleys. It receives the run-off from 580 square miles of mountain and foothill watershed, and has the characteristics of the San Joaquin Valley streams, in that its greatest flood period is during May and June, while the Sacramento Valley streams, being dependent upon rainfall, have their greatest discharge during March. Figure 15 represents the average of the monthly discharge of the Cosumnes at Live Oak Suspension Bridge for the years 1879–1883, and at Michigan Bar for the year 1908. The average annual flow is 1,043 cubic feet per second, but the flow from August to December, inclusive, is very low.

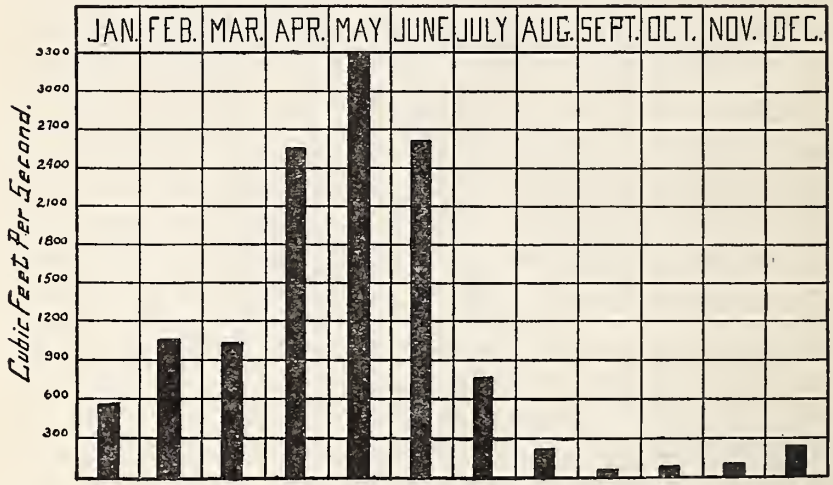

FIG. 15.—Average monthly discharge of Cosumnes River.

The first diversions from the Cosumnes were for mining purposes; but as mining activity decreased as a result of the Anti-Débris Act, an attempt was made to use the ditch systems for irrigation purposes, with the result that about 1,000 acres of trees and vines were irrigated at one time in the foothill region. This has decreased until probably not more than 100 acres are irrigated at present. Trees and vines prosper along the Cosumnes, and irrigation would increase their yield, but as the artificial application of water is not absolutely necessary in this region the practice was discontinued.

Water is sold for gardens and lawns at the rate of 10 cents per miner's inch per 24 hours. The former practice was to sell the water at so much per season, the price being set by the ditch superintendent. Although he considered the acreage, type of soil, and crop, the charge decided upon was not directly upon the acreage or quantity of water to be used, and was not uniform.

SAN JOAQUIN DELTA LANDS.

At the extreme northern part of the San Joaquin Valley and extending westerly from Stockton about 18 miles are the delta lands, commonly known as the Stockton Islands. The entire delta is traversed by the main San Joaquin River. Its three important branches, known as Old River, Middle River, and New River, cut the delta lands into numerous tracts. These lands lie below the high-tide level and in their natural state are covered with a dense aquatic growth. The soil therefore consists of river and tide silts intimately commingled with vegetable matter in various stages of decomposition. It is a peat soil, dark in color, has a coarse mulch-like structure, will float in water, and is uniform to a depth of 6 to 60 feet. Where agriculture is practiced it is necessary to protect the lands against high tide and flood stages of the river by building levees 10 to 15 feet high along the stream, forming a complete inclosure of the island to be developed. The area of the lands that have been reclaimed is about 200,000 acres, the most important of which are the Roberts, Union, Woodward, Victoria, Jersey, and Grant Islands and the Rindge tracts. The construction of protection levees necessitates large costly dredges, which preclude the possibility of reclaiming small areas, and the work generally is done by reclamation districts, in which the cost is assessed pro rata upon the owners of the lands benefited. During the process of reclamation a great many of the natural channels have been enlarged and numerous canals have been built connecting the more important branches of the river. These waterways afford exceptionally good transportation facilities for marketing the products of the islands. It is now the general practice to build the levees at some distance back from the river, utilizing the willows and tules along the banks as a protection against wave action. The crown and inner slope of the levee is plowed and harrowed and generally kept free from trees and vegetation. Drainage channels are constructed through the tract to be reclaimed and the drainage water is pumped into the river. The breaking down of the vegetable matter in the soil after being reclaimed causes a settling of 4 to 8 inches per annum and the levees therefore require much additional work before the necessary height is permanently attained.

When the lands are reclaimed and planted to crops they are irrigated by a unique method in which drainage is an important feature. The winter rains are sufficient for the production of grain, but all the important vegetable crops of the islands which depend upon summer growth are necessarily irrigated. Water is admitted to the reclaimed lands through head gates placed in the levees, or by means of siphons made of cast-iron or riveted steel pipe 8 or 10

inches in diameter, placed across the levee, with a small hand pump on the crest for starting purposes. The siphons are disconnected easily and moved by barge wherever desired. The main supply ditch furnishes water to numerous small distributing laterals. These ditches generally are made 1 foot wide and 18 to 24 inches deep and spaced 60 to 80 feet apart. Since the land is quite level the water fills the ditches to within a few inches of the top, flows slowly through them, and discharges into drainage channels. The soil is so loose that there is little capillarity, as is evidenced by the fact that the soil may be saturated by subirrigation to within 4 inches of the surface without wetting it. Keeping the water in circulation prevents the soil from so-called "souring." The method of subirrigation as practiced in the San Joaquin delta lands would prove ruinous undoubtedly in heavier soils containing much alkali. While alkali salts are in the peat lands in considerable amounts, it is not anticipated that they will be a source of damage in the future because of the very low capillarity. Water is kept running in the ditches until it may be squeezed from a handful of surface soil.

The principal crops of these lands are potatoes, beans, asparagus, onions, celery, and barley. The soil is very rich and unusually large crops are obtained. Onions often are grown between rows of asparagus. Barley is used as a rotation crop with potatoes in alternate years, and beans often are planted as a second crop after potatoes or grain have been harvested. Celery is the only crop grown in the islands that is surface irrigated, and the growing of this is rather a new undertaking. It is irrigated by flooding the surface to a depth of $1\frac{1}{2}$ inches for a period of four days after planting, the water being drained off by small lateral ditches. Since successful irrigation in this region seems to demand a high ground-water table and alfalfa does not thrive on the peat lands, but little is grown.

POSSIBLE FUTURE DEVELOPMENT OF THE VALLEY.

The San Joaquin Valley is one of the most important agricultural districts in the United States and is noted for its productiveness and adaptability to a wide range of crops. Over the bulk of the valley floor irrigation is necessary to make the land productive; therefore the value of the lands to the people who own them and to the State will be proportionate to the area irrigated.

Much has been written concerning the present laws of California and their inability to cope with the water question, but thus far little benefit has been derived from the discussion. The agricultural development of the State is seriously handicapped by lack of State control of the water resources, and too great an opportunity is offered for unscrupulous land and water schemes, whereby the settler

stands the loss. There is plenty of evidence in various parts of the valley where appropriators are running more water than their patrons can use, apparently for the purpose of establishing rights to as great a flow as possible. This prevents other ditches from getting as much water as their patrons should have and curtails further development. It waterlogs the land and thus proves a loss to the settler, but by overappropriating this natural resource the promoter is enabled to sell land at a fancy price where no sales could be made if the lands were dry.

During the Mexican rule 17 grants of land, aggregating 634,000 acres, were given in the San Joaquin Valley, and of this area 300,000 acres lie in the valley basin. They were early valued for stock-raising purposes because of large river frontage and large acreage in one body. Several of these grants fell into the control of a few men, who, by a combination of riparian and appropriators' rights, involved their neighbors in litigation, secured injunctions stopping others from diverting water for irrigation, and by various costly processes of law exhausted their adversaries' capital until they had either acquired the rights of or driven away enough irrigators to dominate some of the principal streams. That, however, has not settled the question of water rights, and it is a significant fact that most of the canal companies diverting water from Kings, Kaweah, and Tule Rivers make a separate item for litigation and include litigation charges in the annual maintenance costs.

Much money has been wasted in the construction of irrigation systems which have had to be abandoned, and some of which never carried water because of injunctions. Whether or not an appropriation of water is valid can be determined only by constructing the canals and ditches and diverting the water, which will precipitate litigation. This manifestly is wrong, and such waste would not be possible if the State authorities had to be consulted regarding the validity of water rights before construction work began, and appropriations would be permitted only if the water supply was sufficient.

As stated [1] in the report made by a congressional committee in 1874, "so-called canals and ditches have been constructed without regard to permanency or regimen or the least foresight, and the 'dog-in-the-manger' policy has been carried by those claiming the water rights, some of which are of the most extravagant character, and if fully persisted in must prevent the full development of which irrigation is capable."

It has long been recognized that "water is the lifeblood of the country," and "water is the wealth of California." In southern California, where the duty of water is the highest in the United

[1] Ex. Doc. 290, 1st sess., 43d Cong., "Irrigation in California."

States, the pioneer methods of the old Spanish irrigators of having short ditches to deliver water to pastures and grain fields for carrying stock through dry seasons have advanced, due to scarcity of water and extensive settlement, until the present excellence was reached. Water is applied less lavishly to larger areas with better results, canals have been reconstructed on higher lines to utilize the surface waters to the best advantage, and a much greater improvement has been due to the utilization of reservoir sites and improvement of underground water supplies. A further saving has necessitated the replacement of old earth ditches by cement lining and underground cement pipe to eliminate evaporation and seepage losses.

The San Joaquin Valley, with its more abundant water supply, is in the early stages of such improvement, though its water resources are far from being developed to their capacity. Wasteful methods have resulted in waterlogging large portions of the older irrigated sections, and but little effort has been extended toward restoring them to their former state of productiveness. Drainage, therefore, is emphatically needed and should go hand in hand with irrigation as a prevention and cure for such damage. It is estimated that there are more than 10,000 pumping plants in California for irrigation purposes, and of this number probably 5,000 are in the San Joaquin Valley. It is a phase of irrigation that is making rapid strides, although only in its infancy.

The San Joaquin Valley has made a great growth. The acreage under irrigation is increasing each year, and in the irrigated sections there is apparent progress and prosperity. A large acreage is being planted to vines and trees and other permanent crops, and much care and intelligence are shown in the work. The natural advantages of the valley will insure its continued progress, but it can not reach the development of which it is possible and provide homes for the greatest number unless some of the handicaps are removed.

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